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A New Organic Amendment Based on Insect Frass for Zucchini (*Cucurbita pepo* L.) Cultivation †

Jamaa Zim [1,*], Amlal Aitikkou [2], Moulay Hicham EL Omari [2], Soumia EL Malahi [3,4], Khalid Azim [5], Abdelaziz Hirich [6], Abdelaziz Nilahyane [6] and Ali Oumouloud [2]

1 Department Plant Protection, Agronomic and Veterinary Institute Hassan II, Agadir 80000, Morocco
2 Department of horticulture, Agronomic and Veterinary Institute Hassan II, Agadir 80000, Morocco; aitikkouamlal98@gmail.com (A.A.); h.elomari@iav.ac.ma (M.H.E.O.); ali.oumouloud@gmail.com (A.O.)
3 Faculty of Science, Ibn Zohr University, Agadir 80000, Morocco; s.elmalahi@uca.ma
4 Higher School of Technology, University of Cadi Aayad, El Kelâa des Sraghna 43000, Morocco
5 Integrated Crop Production Research Unit, Regional Center of Agricultural Research of Agadir, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, Rabat 10090, Morocco; azim.khalid@yahoo.fr
6 African Sustainable Agriculture Research Institute (ASARI), Mohammed VI Polytechnic University (UM6P), Laayoune 70000, Morocco; abdelaziz.hirich@um6p.ma (A.H.); abdelaziz.nilahyane@um6p.ma (A.N.)
* Correspondence: j.zim@iav.ac.ma
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Abstract: Insect frass is considered as a sustainable resource for plant nutrition. This new amendment is characterized by a high salinity (EC) which constitutes an issue for its agronomic utilization. The objective of this work is to evaluate the effect of four organic amendments with different EC: frass of *Hermetia illucens* (15.19 mS/cm), frass of *Tenebrio molitor* (6.47 mS/cm), vermicompost (2.07 mS/cm), and cattle manure (1.33 mS/cm), on zucchini crop. The results showed a great improvement of the agronomic parameters of zucchini using frass of *T. molitor* insects. This study shows that insect frass could be potential alternatives of conventional amendments and may have positive impact on sustaining agricultural production.

Keywords: cattle manure; *Cucurbita pepo* L.; insect frass; plant nutrition; salinity; vermicompost

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1. Introduction

Global population growth requires the development of new strategies for sustainable food production [1]. Mass rearing of insects could be a sustainable and ecological alternative for animal protein production [2]. However, the insect farming activity generates large amounts of excreta called insect frass [3]. The use of these frass as biofertilizers could represent an opportunity to decrease the use of chemical fertilizers and thus contribute to the development of resilient and sustainable agriculture. Studies have highlighted the use of insect frass as organic fertilizers, such as those of *Tenebrio molitor* [4] and the fly *Hermetia illucens* [5]. These studies have shown that insects frass are rich in plant-available nutrients and microorganisms and promote plant growth and natural defense. The salinity of these new amendments poses a real problem in their use especially at high doses. In this context, the present work consists in determining the effects of four organic amendments, namely: vermicompost, cattle manure and the frass of *Hermetia illucens* and *Tenebrio Molitor*, on growth and production of zucchini cultivated under greenhouse.

2. Materials & Method

2.1. Location of the Trial and Plant Material

This study was conducted between June and September 2021 at the experimental farm of the Horticultural Complex of Agadir. The trial took place in a greenhouse type "multi

Chapel" with an area of 48 m^2. A hybrid F1 variety "Leen" of zucchini was used as plant material of the study.

2.2. Preparation of the Culture Substrates

The four applied organic amendments are cattle manure, vermicompost and two biofertilizers based on the frass of *Tenebrio molitor* and *Hermetia illucens*. Sand was used as a control substrate. Four mixtures were prepared based on sand to which, one of the organic amendments was added. The mixtures were made at a ratio of 1 (organic amendment): 20 (sand) in terms of volume [6]. A chemical analysis was made to investigate the effect of the organic amendments on the physico-chemical characteristics of the mixtures, Table 1 below summarizes the different chemical characteristics of the tested amendments.

Table 1. Chemical characteristics of the tested amendments.

Chemical Characteristics	Composition				Unit
	Hermetia illucins Frass	*Tenebrio molitor* Frass	Vermicompost	Cattle Manure	
OM	8.02	7.65	7.87		%
C/N	4.02	3.84	20.20	20.00	-
pH	7.05	5.97	8.60	8.13	-
EC	15.19	6.47	2.07	1.33	(mS/cm)
N	1.18	1.16	0.23	0.62	%
K	0.38	0.35	0.38	0.61	%
Ca	3.13	2.44	46.28	261.30	Meq/100 g
Mg	6.30	66.36	22.86	84.70	Meq/100 g
Na	60.23	11.92	7.52	-	Meq/100 g
Zn	17.51	10.34	2.41	1.49	mg/Kg
Mn	1.87	1.87	1.87	2.68	mg/Kg
Fe	6.20	15.77	3.48	64.00	mg/Kg
Cu	0.92	1.05	0.16	0.20	mg/Kg

2.3. Experimental Design

The trial was conducted in a randomized complete block design with five replications. Each block was composed of 20 zucchini plants, planted in 8-L containers. The experimental unit corresponds to 4 plants with a spacing of 50 cm between the pots and 80 cm between the blocks.

2.4. Statistical Analysis

The analysis of variance (ANOVA) was performed with the Minitab 16 (Minitab Inc. State College, PA, USA). Tukey's test was adopted to compare the means between different treatments, at 5% significance level.

3. Results

Growth Attributes

Statistical analysis of data related to leaf area, leaf dry weight, number of fruits, and average fruit weight per plant, fresh root weight and plant height revealed that the differences among treatments were very highly significant. Comparison of the means by Tukey's test distinguished different groups. For leaf area *Tenebrio molitor* frass (FTM) followed by Cattle manure (Cm) showed good vegetative growth. FTM and Vermicompost (V) showed the best results for dry leaf biomass with means of 42.26 and 40.60 g/plant, respectively, followed by Cm and *Hermetia illucins* frass (FBSF) which represented 36.79 and 36.48 g/plant respectively and finally, the control (T) with 30.94 g/plant. The number of fruits per plant was maximum for the FTM treatment, followed by V, Cm, FBSF and T with average values of 2.95, 2.65, 2.5, 2.45 and 2 fruits/plant respectively. For the fruits weight, two homogeneous groups were observed, the FTM and V treatments were represented by the first group and the Cm, FBSF and T treatments were included in the second group. The FTM amendment resulted in the highest fresh weight of the zucchini plant roots, which

was around 34.45 g. The V, Cm and FTM amendments resulted in average values of 33.95; 30.49; and 27.47 and 24.05 g/plant respectively. The highest value of final plant height of zucchini was recorded in the plants amended by FTM followed by V, Cm, FBSF and finally by T with values of 113.4, 111, 106.6, 102.6 and 98.4 cm respectively. Table 2 summarizes the effect of the different organic amendments on different agronomic parameters.

Table 2. Effect of different organic amendments on growth attributes. The means followed by the same letter are not statistically different at $p < 5\%$ according to the Tukey test.

	Number of Fruits per Plant	Plant Height (cm)	Dry Weight of Leaves (g)	Leaf Area (cm^2)	Fresh Root Weight (g)	Average Fruit Weight (g)
Control (T)	2.45 (b)	102.7 (e)	30.94 (c)	16,956.75 (d)	24.06 (d)	292.55 (b)
Cattle manure (Cm)	2.95 (a)	106.6 (c)	36.79 (b)	18,839.46 (b)	27.48 (c)	299.47 (b)
Vermicompost (V)	2.65 (ab)	111.0 (b)	40.61 (a)	19,541.45 (a)	33.95 (a)	320.42 (a)
Hermetia illucins frass (FBSF)	2.50 (b)	106.1 (d)	36.48 (b)	18,049.94 (c)	30.50 (b)	298.42 (b)
Tenebrio molitor frass (FTM)	2.00 (c)	114.4 (a)	42.26 (a)	19,905.52 (a)	34.45 (a)	323.42 (a)

4. Discussion

The obtained results show that the substrates amended by FTM recorded the highest values in terms of plant height, leaf area and fresh and dry weight of the vegetative part. This can be explained by the availability of mineral elements easily assimilated by the plant in the substrates amended by the insect's frass, as well as by the heterogeneity of the quantities of fertilizing elements in the soil. This could also be explained by the rate of absorption of mineral salts by the roots and by the quantities of nitrogen and phosphorus consumed, which stimulate the synthesis of proteins and consequently the accumulation of dry matter as observed under the insect's frass and vermicompost treatments. While for the control treatment (100% sand), the low values of the growth parameters recorded could be explained by the use of plant assimilates in fruit enlargement rather than in vegetative growth. Indeed, similar results to the effect of FTM were found by [5] who revealed that FTM may have some success in improving lettuce yield. Fresh weight, length of aerial part, basal stem width, and chlorophyll content of leaves all indicated significant increases with Molitor's tapeworm taper application compared to the negative control. Also, Przemieniecki et al. [7] found that soil fertilization with meal from *Tenebrio larvae* increased fresh and dry weight of biomass compared to mineral nitrogen fertilizer. It is noted that excessive Na^+ uptake can cause evident leaf damage, reduction in leaf number, leaf area recession and reduction in fresh and dry weight [8], which may explain the reduction in leaf number and fresh and dry weight of the black soldier treatment, since it has a higher Na^+ content. Graifenberg et al. [9] reported that in response to salinity there is a reduction in dry weight mainly in the aerial part of the zucchini plant and that the ratio of the dry weight of the aerial part to the dry weight of the root part decreases under salt stress conditions, which means that the dry weight of the roots is less affected by salinity. The positive results obtained by vermicompost amendment in terms of number of fruits per plant and average fruit weight of zucchini are confirmed by [10] who showed that vermicompost had significant effects on fruit weight.

5. Conclusions

Hermetia illucens frass is very saline due to the high content of mineral salts. This negatively influenced the growth and development of zucchini plants with a low yield compared to plants fertilized with *Tenebrio molitor* frass which recorded a high yield. The two amendments that provided the best vegetative growth of the zucchini plants were the *Tenebrio molitor* frass and vermicompost. These amendments showed adequate performance in terms of veg-etative growth parameters and fruit size. The insect frass-based organic amendments (e.g., *Tenebrio molitor* frass) improved the yield of zucchini plants by 62% compared to control, suggesting that these products could be potential alternatives to chemical fertilizers.

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