RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
56 (1) 370-378, 2024
http://doi.org/10.54910/sabrao2024.56.1.33
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

EFFECT OF DECOMPOSED PALM RESIDUES AND FOLIAR APPLICATION OF *MALVA PARVIFLORA* L. LEAF EXTRACT ON EGGPLANT GROWTH AND YIELD

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SUMMARY

Determining the effects of organic fertilizer and foliar application of mallow leaf extract on the growth and yield of eggplant was the aim of this latest study held in spring 2021 in the Al-Najaf Province, Iraq. The treatments comprising adding decomposed palm waste to the soil at three levels (0, 16, and 32 mg ha^{-1}), foliar application of mallow leaf extract at three concentrations (0, 0.2, and 0.4 gm.l^{-1}), and their interactions incurred probing in eggplants. The experiment began in a randomized complete blocks design (RCBD) with factorial arrangement and three replications. The results obtained through the analysis of variance continued to further evaluation through the least significant difference test to compare and separate the various means. The results showed that organic fertilization with decomposing palm residues at 32 mg ha^{-1} significantly outperformed the other treatments for plant height, total leaves, dry weight of vegetative growth, fruits per plant, yield per plant, total yield, nitrogen (%), and total chlorophyll content in the leaves.

Keywords: Eggplant (*Solanum melongena* L.), organic fertilization, *Malva parviflora* L., growth and yield traits, nitrogen, chlorophyll content, carbohydrates

Key findings: Organic fertilization with decomposing palm residues (32 mg ha^{-1}) outperformed the other treatments for plant height, number of leaves, dry weight of vegetative growth, fruits per plant, yield per plant, total yield, nitrogen (%), and total chlorophyll content in the leaves.

Communicating Editor: Dr. Gwen Iris Descalsota-Empleo

Manuscript received: August 3, 2023; Accepted: November 16, 2023.

Citation: Mahmood OH, Jaafar HS (2024). Effect of decomposed palm residues and foliar application of *Malva parviflora* L. leaf extract on eggplant growth and yield. *SABRAO J. Breed. Genet.* 56(1): 370-378. http://doi.org/10.54910/sabrao2024.56.1.33.

INTRODUCTION

The eggplant (*Solanum melongena* L.) is one of the main summer vegetables in Iraq, belonging to the family Solanaceae (Mahmoud and Sadek, 2020). The genus *Solanum* includes 75 genera and more than 2000 species. With a belief that the eggplant's origin is Central India, where its wild ancestors still grow, its domestication occurred in Southeast China, then later introduced by the Arabian community to other regions of the world (Kumar *et al*., 2020; Suirta *et al*., 2021; Mulyana *et al*., 2023).

Descriptions of eggplant fruits include being rich in nutrient elements, such as phosphorus, potassium, calcium, magnesium, sodium, and zinc, in addition to vitamins A, B, and C (Kandoliya *et al*., 2015). Using decomposed organic matter improves the chemical and physical properties of the soil, where the humic material decomposing as hydrophilic colloids have a high surface area relative to their weight, and their absorption capacity becomes more than 300% of their weight, adding a positive impact on the water content balance (Durán-Lara *et al*., 2020).

The change in soil structure and volumetric distribution of pores activates soil microorganisms, improves plant water conditions, and reduces heat, drought, and salinity stresses. The organic fertilizers' application avoids chemical contaminants like nitrates and oxalates (De-Souza-Machado *et al*., 2019). Plant growth indicators improve when the soil gains nutrients for plant growth and development. Such fertilization helps create and strengthen agricultural areas and food systems to sustain human and animal health (Velmourougane *et al*., 2019).

Recent studies chose to use plant extracts to avoid chemical fertilizers and pesticides of different types and compositions with toxic and harmful effects on human and animal life. Therefore, the researchers opted to use safer materials by applying organic fertilizers and extracts of natural and marine plants, which have no harm to the environment, humans, and animal health. In addition to its frequent availability and low prices, one of these plant extracts is the mallow plant extract with characteristics of high nutritional benefits (Meddah *et al*., 2023**)**.

Mallow (*Malva sylvestris* L.) is one of the medicinal plants recognized as common mallow, native to Europe, North Africa, and Asia, which grows wild in the fields. The said plant generally grows in moist areas near marshes, ditches, oceans, riverbanks, and meadows. The *Malva* plant also contains several valuable compounds, such as potent antioxidants, carbohydrates, unsaturated fatty acids, tannins, flavonoids, phenolic compounds, and ascorbic acid, with its flowers and leaves, also used as medicines (Barros *et al*., 2010; Yeole *et al*., 2010; Gasparetto *et al*., 2012).

With the lack of research that dealt with fertilization with decomposed palm residues and foliar application of mallow leaf extracts on eggplant growth and yield, the pertinent study aimed to determine the effects of organic fertilization (decomposed palm residues) and foliar application of mallow leaf extracts and their interaction on growth and production indicators of eggplant**.**

MATERIALS AND METHODS

The presented study on the eggplant determined the effects of organic fertilizer and mallow leaf extract foliar application on the growth and yield of eggplants, held in spring 2021 at the District Al-Haidariya, Al-Najaf Province, Iraq. The nine treatments included adding decomposed palm waste at three levels (0, 16, and 32 mg ha^{-1}) to the soil, three concentrations of mallow leaf extract foliar application, and their interactions with eggplants. The experiment commenced in a randomized complete blocks design (RCBD) with factorial arrangement and three replications.

The experimental field contained random soil samples from different places at 0–30 cm depth. All the soil samples' mixing transpired, making one representative soil sample. Laboratory analyses of the soil sample and irrigation water (from the well) continued for chemical and physical characteristics of the soil and irrigation water at the Department of

Table 1. Chemical and physical properties of the experimental field soil and irrigation water.

Traits	EC (DS m^{-2})	Organic matter (%)	N (mg kg^{-1})	P (mg kg^{-1})	K (mmol l^{-1})	pH	Texture	Sand	Silt	Clay
								g l^{-1}		
Soil	3.5	1.2	4.12	3.74	0.59	7.4	Sandy loam	695	177	128
Water	4.3	___	2.26	3.31	0.78	7.2				

Table 2. Chemical properties of decomposed palm waste.

Traits	N%	P%	K%	C%	B mg kg^{-1}	pH	EC (DS m^{-1})	O.M	C/N %
Values	1.86	0.80	1.30	40.79	13	6.60	6.95	73.33	21.93

Table 3. Biochemical composition of the mallow leaf extract.

Mallow extract components			
N	1.97 %	Glutamic acid	113.54 mg kg^{-1}
P	0.95 %	Serine	4096.22 mg kg^{-1}
K	1.75 %	Glysine	498.92 mg kg^{-1}
Ca	2.93 %	Threonine	9022.53 mg kg^{-1}
Mg	1.88 %	Valine	898.22 mg kg^{-1}
Na	1.56 %	Phenylalanine	585.78 mg kg^{-1}
Fe	57.0 mg kg^{-1}	Tryptophan	152.35 mg kg^{-1}
Mn	6.9 mg kg^{-1}		
Br	31.0 mg kg^{-1}		
Cu	38.0 mg kg^{-1}		
Zn	28.6 mg kg^{-1}		
Auxin (IAA)	122.36 mg kg^{-1}		
Gibberellin (GA3)	131.95 mg kg^{-1}		
Cytokinins	158.82 mg kg^{-1}		
Vitamin C	312.76 mg kg^{-1}		

Soil Science and Water Resources, College of Agriculture, University of Kufa, located at 32°01′38.0″˝″N 44°22′23.8″, Kufa, Iraq (Table 1).

The seeds used were the eggplant hybrid variety, Black Beauty (of American origin, produced by Bars). Its plants are characteristic of robust growth, and its fruits are black and oval with good gloss, adding to its abundant productivity. The eggplant seeds' sowing happened on February 20, 2021, in plastic dishes after filling them with sandy soil and peat moss (1:2, respectively). After germination and completing the seedlings' growth, the plants' transfer to the field followed. The experiment proceeded in RCBD with a factorial arrangement of two factors and three replications. The first factor was the addition of decomposed palm waste (organic matter) (Table 2) to the soil at three levels (0, 16, and 32 mg ha^{-1}), and the second factor was a foliar application of mallow leaf extracts with three concentrations (0.0, 0.2, and 0.4 gm l^{-1}) (Table 3).

The data recorded for five random plants taken in each experimental unit and replication, with their averages calculated for the growth-related traits, i.e., plant height (cm), leaves per plant (Slinkard and Singleton, 1977), and the dry weight of vegetative growth (g $plant^{-1}$). The vegetative index computation occurred at the end of the experiment by uprooting four plants in each experimental unit without their root mass and cutting their vegetative aggregate into small pieces to increase the surface area for moisture loss. Afterward, these incurred complete drying in the electric oven at 75 °C for 48 h before determining their dry weight.

Yield indicators and their components

Counting the fruits in each eggplant provided the average fruit number per plant. The fruit yield per plant calculation was according to the following equation:

Yield per plant (kg plant $^{-1}$) = The yield of the experimental unit / The number of plants in the experimental unit

The cumulative total yield (mg ha^{-1}) bore calculations according to the fruit collection from a specific area, with the resulting values converted into the fruit yield per hectare.

Chemical indicators of leaves and fruits

The nitrogen (%) in the eggplant leaves' determination used the Kjeldahl Micro apparatus, following the method of Sparks *et al*. (2020). The total chlorophyll pigment in the green leaves (mg 100 g^{-1} fresh weight) continued estimation according to the formula described by Goodwin (1976). The total carbohydrates (%) estimates in eggplant fruits followed Joslyn (1970). Attaining the estimated total flavonoids (mg g^{-1}) in the eggplant fruits employed the colorimetric spectrophotometer by assay for aluminum chloride (Tzanova *et al.*, 2020).

RESULTS AND DISCUSSION

Vegetative traits

Adding decomposed palm residues to the soil significantly affected the eggplant's growth and yield-related traits (Table 4). The decomposed palm residues (32 mg ha^{-1}) provided the highest rates for vegetative growth indicators, including plant height (91.77 cm), total number of leaves (87.06 leaves plant^{-1}), and dry weight of vegetative growth (178.95 g plant^{-1}), compared with eggplants' control treatment (soil only), which gave the lowest rates of 80.94 cm, 75.38 leaves.plant^{-1}, and 159.05 g plant^{-1}, respectively. The reason may be due to the palm residues' prime nutrient content, such as nitrogen, and its positive effect on forming amino acids. These, in turn, help synthesize proteins and nucleic acids, DNA and RNA, as well as building chloroplasts, causing an increase in protoplasm mass, cell division, and building new tissues, increasing plants' growth and development. Organic fertilizers can improve the vegetative system and enhance the growth parameters (Pulunggono *et al*., 2019; Suirta *et al*., 2021).

Table 4. Effect of fertilization with decomposed palm residue and foliar application of mallow leaf extract and their interaction on the vegetative growth indicators of eggplant.

Treatments			Plant height (cm)	Leaves plant^{-1}	Dry weight of vegetative growth (g plant^{-1})
Fertilization levels with decomposed palm residues (mg ha^{-1})	0		80.94	75.38	159.05
	16		86.27	80.20	170.57
	32		91.77	87.06	178.95
$LSD_{0.05}$			0.43	1.57	1.09
Spray concentrations of mallow leaf extract (g l^{-1})	0		84.40	78.02	165.52
	16		86.10	81.64	169.97
	32		88.49	83.97	173.07
$LSD_{0.05}$			0.43	1.57	1.09
Fertilization levels × spray concentrations	0	0	78.69	71.25	155.71
	0.2		80.33	76.71	158.95
	0.4		83.81	78.19	162.48
	0	16	84.50	77.92	165.52
	0.2		86.24	80.73	171.36
	0.4		88.08	81.96	174.83
	0	32	90.00	84.88	175.34
	0.2		91.72	87.47	179.61
	0.4		93.59	88.84	181.89
$LSD_{0.05}$			1.18	3.34	1.92

Additionally, the increase in dry weight of the vegetative parts was due to the enhancement in traits like plant height and the number of leaves (Table 4). These indicators are often associated with an increase in the process of carbon metabolism, which also increases starch and sugars as industrial materials accumulate in the plant, consequently boosting the indicator. The results also implied significant differences between the foliar application of mallow leaf extracts on eggplants and the control treatment. The spraying of mallow leaf extract (0.4 g l^{-1}) on eggplants showed increased values of vegetative indicators, i.e., plant height, leaves per plant, and dry weight of vegetative mass, with values of 88.49 cm, 83.97 leaves.plant^{-1}, and 173.07 g.plant^{-1}, respectively, compared with the eggplants in the control treatment giving the lowest values for these indicators. Such vegetative improvement with mallow foliar extract might be due to the macro- and micronutrients and growth regulator contents (Nowwar *et al.,* 2022; Mulyana *et al*., 2023), including auxin and cytokinin (Table 3). These elements are vital in the physiological processes of the plant. Nitrogen (N) plays an essential role in the construction of various organic compounds inside the plant, involved in constructing chlorophyll pigment, nucleic acids, DNA and RNA, proteins, hormones, and enzymes, as well as, cytochromes that are crucial in the processes of photosynthesis and respiration (Bilen *et al*., 2020; Brown *et al*., 2022).

The physiological processes increase the ability of the plants to manufacture nutrients through photosynthesis, and its positive result increases the indicators of vegetative growth, as represented by the plant height, the number of its leaves, and the total vegetative growth. The phosphorus effectively stimulates enzymatic reactions to build vital and energy compounds, increasing the effectiveness of the photosynthesis process in the plant, which had a positive effect on boosting the manufacture of dry matter and its accumulation in the plant with the achieved enhancement in vegetative indicators (Al Murad *et al.,* 2021). The potassium also affects the process of opening and closing the stomata, therefore, boosts the absorption of water and nutrients by the plants, works to activate the photosynthesis process, and affects cell division and elongation, which eventually increase the vegetative growth (Rawat *et al*., 2022).

Boron is a necessary element also contained in the plant extract, which contributes to plants’ growth and development, affecting most of the plant's vital processes, including the transport of sugars, the formation of carbohydrates, the growth of the pollen tube, the increase in fertilization, and the preservation of the water balance in the cell. Such an element in the mallow plant extract is essential in synthesizing the amino acid tryptophan. Likewise, tryptophan initiates the synthesis of auxin and indole acetic acid, increasing cell division and elongation and the number of leaves through the process of meristematic cells’ division for the leaf primordial principle’s formation, which expands the leaf area for superior vegetative growth (Chen *et al*., 2023).

The growth regulators auxin and cytokinin found in the contents of the mallow plant extract showed a positive role in the eggplant’s growth and development (Table 3). According to Beemster and Baskin (2000), auxin has a crucial function in promoting cell division and enhancing the efficiency of photosynthesis. Additionally, auxin contributes to the light reaction by facilitating the production of pigments. According to Joshi *et al.* (2011), the process of cell division and elongation, along with stimulating physiological processes and the subsequent increase in chlorophyll concentration in leaves, contribute positively to enhancing the plant's efficiency in the photosynthetic process. Considering this, there has been a notable rise in the production and accumulation of carbohydrates, resulting in enriched vegetative indicators (Kapoor *et al.,* 2022).

The interaction between the treatments of fertilization with decomposed palm residues and spraying with mallow extracts significantly influenced vegetative growth indicators. The interaction between fertilization of residues (32 mg ha^{-1}) and foliar application of mallow leaf extracts (0.4 g l^{-1}) remarkably improved the plant height, leaves per plant, and dry weight of vegetative mass with values of 93.59 cm, 88.84 leaves plant^{-1}, and 181.89 g plant^{-1} compared with the control treatment giving the lowest rates of 78.69 cm, 71.25 leaves plant^{-1}, and 155.71 g plant^{-1}, respectively. The observed augmentation of vegetative features can be because of the substantial role of auxin promoting cellular division and enhancing the photosynthetic process efficiency, as well as, its crucial part in the light reaction synthesizing pigments. Joshi *et al.* (2011) reported the successful enhancement of the plant's photosynthetic efficiency results from the interaction of cell division and elongation and the stimulation of physiological mechanisms, raising chlorophyll concentration within the leaves. The presented outcome has seen a substantial rise in the synthesis and accumulation of carbohydrates, resulting in notable enhancements in vegetative indices (Ghorbani *et al.,* 2011).

Yield and physiological traits

A notable effect of fertilization with decomposed palm residues emerged on quantitative and qualitative yield indicators represented by fruits per plant, fruit yield per plant, total fruit yield, leaf nitrogen (%), leaf chlorophyll content, fruits' carbohydrates (%), and phenols and flavonoids content in fruits (Tables 5 and 6). A significant enhancement in the fruit yield and physiological parameters occurred by adding decomposed palm residues (32 t ha^{-1}), which gave the highest rates of 22.11 fruits plant^{-1}, 3.50 kg plant^{-1}, 58.45 mg ha^{-1}, 1.86%, 48.30 mg 100 g^{-1} fresh weight, 22.49%, 17.40, and 9.84 mg g^{-1}, respectively, compared with the control treatment. The lowest rates from the control for these indicators amounted to 14.68 fruits plant^{-1}, 2.10 kg plant^{-1}, 33.88 mg ha^{-1}, 1.43%, 20.56 mg gm^{-1} fresh weight, 11.52%, 9.53 and 5.35 mg gm^{-1}, respectively. An explanation might be the provision of the nutrients necessary for plant growth and development and their positive role in increasing metabolism and transporting the bulk of carbohydrates after converting them from the leaves to the fruits (Englyst *et al*., 2007).

The addition gave nutrients the plant needs that contribute to carbon metabolism, respiration, and protoplasmic construction processes (Aguirre *et al*., 2018). Adding organic matter to the plant supplied the necessary elements, such as nitrogen and phosphorus (Pettit, 2004). Nitrogen works to increase the mass of protoplasm and cell division, enhancing the size of the vegetative system of the plant, which leads to an increase in the yield (Malvi, 2011). Transmitting manufactured materials also affects the leaves to the fruits, as impacted by potassium significantly (Bhatla *et al*., 2018). The increase in yield refers to the role of organic fertilizers in improving the chemical and physical properties of the soil (Table 1). As a result, the soil's ability to retain moisture provides better conditions for the growth of the root system, increasing the activity and number of microorganisms, thus raising their decomposition and readiness of the nutrients necessary for plant growth (Zhang *et al*., 2013).

The foliar application of mallow leaf extracts significantly affected quantitative and qualitative yield indicators, including fruits per plant, yield per plant, total yield, nitrogen (%) and total chlorophyll content in leaves, carbohydrates (%), phenols, and complete flavonoids content in fruits (Tables 5 and 6). The mallow leaf extract's foliar application (0.4 g l^{-1}) showed the highest rates for the quantitative and qualitative yield indicators, i.e., 20.20 fruits plant^{-1}, 2.45 kg plant^{-1}, 40.20 mg ha^{-1}, 2.57%, 39.43 mg 100 g^{-1} fresh weight, 19.14%, 17.46, and 11.32 mg g^{-1}, compared with the control treatment with the lowest rates for those indicators (16.56 fruits plant^{-1}, 2.45 kg plant^{-1}, 40.20 mg ha^{-1}, 0.87%, 28.57 mg g^{-1} for fresh weight, 15.30%, 6.99, and 3.95 mg g^{-1}, respectively). The increase in the quantitative and qualitative indicators might be due to the extract of the mallow plant containing some macro- and micro-nutrients, playing a primary role in several physiological and vital processes for the benefit of the plant, including amino acids, nucleic acids, proteins, and chlorophyll and organic compounds (Zohra *et al*., 2012) (Table 3).

Table 5. Effect of fertilization with decomposed palm residues and foliar application of mallow leaf extract and their interaction on the fruit yield and its components of eggplant.

Treatments			Fruits plant^{-1}	Yield per plant (kg plant^{-1})	Total yield (mg ha^{-1})
Fertilization levels with decomposed palm residues (mg ha^{-1})	0		14.68	2.10	33.88
	16		18.31	2.86	43.82
	32		22.11	3.50	58.45
$LSD_{0.05}$			0.49	0.11	2.26
Spray concentrations of mallow leaf extract (g l^{-1})	0		16.56	2.45	40.20
	16		18.34	2.73	44.30
	32		20.20	3.28	51.65
$LSD_{0.05}$			0.49	0.11	2.26
Fertilization levels × spray concentrations	0	0	13.84	1.91	31.42
	0.2		14.59	2.06	33.50
	0.4		15.61	2.33	36.71
	0	16	16.13	2.43	38.04
	0.2		17.87	2.75	42.15
	0.4		20.92	3.40	51.26
	0	32	19.70	3.02	51.13
	0.2		22.56	3.39	57.24
	0.4		24.08	4.10	66.99
$LSD_{0.05}$			0.77	0.21	3.39

Table 6. Effect of fertilization with decomposed palm residues and foliar application of mallow leaf extract and their interaction on the biochemical composition of the leaves and fruits of eggplant.

Treatments			Leaf nitrogen (%)	Total chlorophyll (mg 100 g^{-1} fresh weight)	Total carbohydrates (%)	Total phenols (mg g^{-1})	Total flavonoids (mg g^{-1})
Fertilization levels with decomposed palm residues (mg ha^{-1})	0		1.43	20.56	11.52	9.53	5.35
	16		1.60	31.07	17.10	12.95	8.02
	32		1.86	48.30	22.49	14.70	9.84
$LSD_{0.05}$			0.19	0.74	0.23	1.21	1.42
Spray concentrations of mallow leaf extract (g l^{-1})	0		0.87	28.57	15.30	6.99	3.95
	16		1.45	31.92	16.66	12.72	7.95
	32		2.57	39.43	19.14	17.46	11.32
$LSD_{0.05}$			0.19	0.74	0.23	1.21	1.42
Fertilization levels × spray concentrations	0	0	0.66	17.42	9.79	4.75	2.62
	0.2		1.24	19.50	11.04	9.62	5.38
	0.4		2.38	24.75	13.73	14.21	8.04
	0	16	0.85	26.11	15.12	6.94	3.73
	0.2		1.39	29.47	16.66	13.37	8.09
	0.4		2.57	37.64	19.51	18.53	12.25
	0	32	1.09	42.18	21.00	9.29	5.49
	0.2		1.71	46.80	22.27	15.18	10.37
	0.4		2.77	55.91	24.19	19.64	13.65
$LSD_{0.05}$			0.31	1.56	0.35	2.42	1.86

The enzymes' stimulation increased the number of cells and their size, increasing the vegetative indicators, which, in turn, reflect the provision of sufficient food to turn the vegetative buds into flowers and reduce the competition between flowers for the nutritional content of the plant, necessitating an upsurge in the indicators of the yield and its components (Batiha *et al.*, 2023). The improvement of the nutritional status of the plant contributed positively to enhancing the vegetative indicators (Zohra *et al.*, 2012) (Table 4), as reflected ideally in the quantitative and qualitative yield indicators of the eggplant plant (Tables 5 and 6). The interaction between the treatments of fertilization with decomposed palm residues and foliar application of mallow extracts, markedly impacted the quantitative and qualitative indicators, i.e., 4.10 kg plant^{-1}, 66.99 mg ha^{-1}, 2.77%, 55.91 mg 100 g^{-1} fresh weight, 24.19%, 19.64, and 13.65 mg gm^{-1} compared with the control treatment attaining the lowest rates (13.84 fruits plant^{-1}, 1.91 kg plant^{-1}, 31.42 mg ha^{-1}, 0.66%, 17.42 mg 100 g^{-1} fresh weight, 9.79%, 4.75, and 2.62 mg g^{-1}, respectively). Overall, the fertilization with decomposed date palm residues (32 mg ha^{-1}) and foliar application of mallow leaf extract (0.4 g l^{-1}) revealed the best rates for the eggplant's vegetative and quantitative indicators.

CONCLUSIONS

The combined application of organic fertilizer and mallow leaf extracts can be an effective strategy for enhancing the productivity of eggplants. Further research could explore the specific mechanisms through which these treatments positively impacted growth and yield indices.

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