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# Assessment of compost quality and usage for agricultural use: a case study of Hebron, Palestine

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**Abstract** Complying with the technical specifications of compost production is of high importance not only for environmental protection but also for increasing the productivity and promotion of compost use by farmers in agriculture. This study focuses on the compost quality of the Palestinian market and farmers' attitudes toward agricultural use of compost. The quality is assessed through selection of 20 compost samples of different suppliers and producers and lab testing for quality parameters, while the farmers' attitudes to compost use for agriculture are evaluated through survey questionnaire of 321 farmers in the Hebron area. The results showed that the compost in the Palestinian markets is of medium quality due to partial or non-compliance with the quality standards and guidelines. The Palestinian farmers showed a positive attitude since 91.2% of them have the desire to use compost in agriculture. The results also showed that knowledge of difference between compost and chemical fertilizers, perception of compost benefits, and previously experiencing problems in compost use are significant factors affecting the farmers' attitude toward the use of compost as an organic fertilizer.

**Keywords** Compost · Organic fertilizer · Attitude · Compost quality · Manure

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## Introduction

Composting is an environment friendly recycling method of organic waste. It can significantly reduce the waste stream volume since the organic waste is the largest waste fraction of municipal solid waste especially in developing countries (SIDA, Swedish International Development Cooperation Agency 2006; U.S. Environmental Protection Agency (USEPA) 1995; Colón et al. 2010; Al-Khatib et al. 2010). Compost is a key environmental and social factor which can play an important role in organic agriculture through positively impact of soil productivity and household income, and can achieve food security by improving soil fertility and water holding capacity (SIDA, Swedish International Development Cooperation Agency 2006; Weber et al. 2007; Achiba et al. 2009). Compost quality plays an important role in its marketing and encourages farmers to use it in agriculture (Soobhany et al. 2015). The quality of domestic compost has environmental and public health significance of their users, and society in general (Domingo and Nadal 2009; Vázquez and Soto 2017). Beside the economic benefit of the compost producers, many environmental benefits can be gained, including but not limited to, reduction of green gas emissions thus contributing to mitigation of climate change effects (Mohee et al. 2015).

Under resource constraints on external farm inputs faced by farmers in developing countries, sustainable agriculture practices that depend on renewable farm resources and/or other local resources considered a desirable option to enhance agriculture yield. In Palestine and since the beginning of year 2000 (Second Palestinian Uprising) due to Israeli invasions to the Palestinian areas, sever restrictions were imposed on the Palestinian territories that resulted in restrictions on the movement of goods. These restrictions prohibited access to chemical fertilizers and cause deterioration in agriculture products. Accordingly, the Ministry of Agriculture (MoA) issued a call for businesses, investors, and agricultural associations to invest in the production of organic fertilizers in order to compensate for the shortage of fertilizers in the market (Ministry of Agriculture (MoA) 2011).

The potential for compost production in Palestine is relatively high due to the large quantities of manure production as shown in Fig. 1. In addition, large quantities of municipal solid wastes recurrently generated and estimated to be 3,268,430.0 t based on the population projection by the Palestinian Central Bureau of Statistics (Palestinian Central Bureau of Statistics (PCBS) 2017) considering the generation rate of 0.66 kg/capita/day (IFC (International Finance Cooperation) 2012). This waste stream contains at least 46.0% organic waste (IFC (International Finance Cooperation) 2012) of which at least 70% is compostable. However, the local production of organic fertilizer in the Gaza Strip is 66,800 $m^3$/year, which represents only 8.5% of the required quantities (Nassar et al. 2009). Nassar (2015) reported that the compostable organic waste in Gaza Strip is around 800,000.0 t/year.

The demand on organic fertilizers in Palestine is increasing. Farmers in Gaza import huge amounts of compost material to improve the soil conditions (Environmental Quality authority (EQA) 2007; Nassar 2015). Through a study conducted by Solutions for Development Consulting (2009) found that the current practices of use of compost are concentrated in irrigated agriculture as shown in Fig. 2.

HydroplanIngenieur-GesellschaftmbH (2013) in cooperation with Al-Jaar Establishment for Environmental & Industrial Consultations (AEEIC) reported that the percentage of local Palestinian agricultural holdings which use organic fertilizers or animal manure is 57.2% in the year 2005, and the remaining 42.7% agricultural holdings use the chemical fertilizers. Further, the study conducted technical and financial analysis of construction and operation of windrow composting plant of capacity 40,000.0 t per annum and showed the feasibility of compost production in Palestine with a payback period of 2.44 years and internal rate of return of 37%. Mafarjeh (2011) studied the feasibility of organic waste composting at Beit Liqia Village in Palestine and found that composting is a feasible solid waste management option. Therefore, the promotion of composting for agricultural uses can significantly contribute to solve the problem of shortage of chemical fertilizers in the market as well as the problems of solid waste management (Proietti et al. 2016).

However, the farmers' perception and their understanding of the benefits of compost can increase their

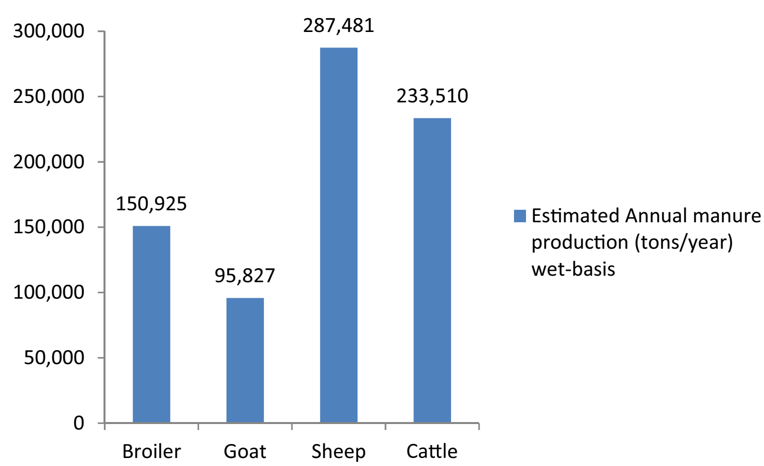


**Fig. 1** Estimated annual manure production in Palestine (2012). *Source:* adapted from HydroplanIngenieur-GesellschaftmbH (2013)

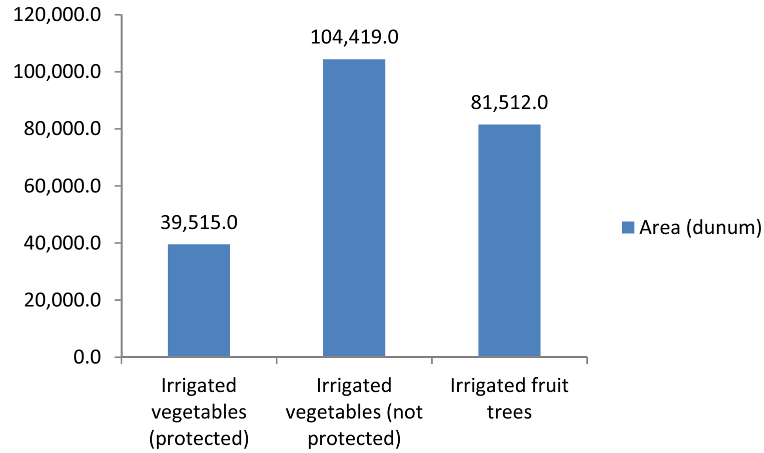


**Fig. 2** Distribution of agricultural areas that use compost in Palestine

willingness and attitudes toward compost use in agriculture. The farmers' socio-economic conditions, experience, size of agricultural land, types of crops, compost prices, etc. are all important factors that could affect the willingness to use compost in agriculture. Danso et al. (2002) studied the farmers' perception and willingness to pay for urban waste compost in Ghana, and the results showed that majority of the farmers have positive perceptions and are willing to use and pay for compost, often without related prior experience. It has been found that the effective demand for compost for agricultural purposes is limited to subsidies (Danso et al. 2006).

On the policy level, the Palestinian National Authority (PNA) sets the National Strategy for Solid Waste Management (NSSWM) in the Palestinian Territory (2010–2014), which aimed in its strategic policy (8) to reduce the greenhouse gases emitted as result of solid waste activities (NSSWM 2010). Reduction of these gases can be achieved through proper management of organic waste like aerobic composting. A study on greenhouse gases conducted by the United Nations Development Program (UNDP) showed that the waste is a major greenhouse gas emitting sector in Palestine and accounted for 23% in 2011 (United Nations Development Program (UNDP) 2015). Further, the Palestinian Standards Institutions (PSI) issued the standard specifications for the organic fertilizers (Compost) in 2012 under the number PS/-2652:2012 to control organic waste composting in Palestine. This specification has been approved and became effective on June 11, 2012.

This study aims to assess the quality of compost currently available in the Palestinian market, and the

**Table 1** Description of variables in the LRM

| Variable | Description | Definition |
|---|---|---|
| $X_1$ | Farmer income | 1 = ≤ 1500; 2 = 1501–2000; 3 = 2001–3000; 4 = 3001–4000; 5 ≥ 4000 |
| $X_2$ | Number of type of plants the farmer grow | 1 = one type; 2 = two types; 3 = three types; 4 = four types |
| $X_3$ | Area of agricultural land (dunum) | 1 = <2; 2 = 2–5; 3 ≥ 5 |
| $X_4$ | Annual compost cost (NIS)[a] | 1 ≤ 300; 2 = 300–500; 3 ≥ 500 |
| $X_5$ | Farmer believes that compost is better than chemical fertilizers | 1 = Yes; 2 = NO |
| $X_6$ | Farmer used compost in the past | 1 = Yes; 2 = NO |
| $X_7$ | Farmer's knowledge that compost resist diseases | 1 = Yes; 2 = No |
| $X_8$ | Farmers perception of compost benefits | Four benefits were listed and the respondents perception was evaluated based on the number of benefits he mentioned as follows: 1 = 1 out of 4; 2 = 2 out of 4; 3 = 3out of 4; 4 = 4 out of 4 |
| $X_9$ | Experiencing problems in compost use in the past | 1 = Yes; 2 = NO |

[a] Annual compost cost is the cost that the farmer is paying annually to buy compost

farmers' attitude toward the use of compost in agriculture. In addition, it predicts the factors that could affect the farmers' attitude toward compost use.

## Research methods

The study incorporated quantitative data into the quality of the compost in the Palestinian market, and other qualitative data to assess the attitudes of farmers in the Hebron area toward the use of compost in agriculture. The quality of compost is evaluated through the collection of 20 samples obtained from different Palestinian and Israeli sources available in the market. These sources included six samples from the Ministry of Agriculture-Jericho (Mothalath, Thinnaba, Qawasmeh, Nasrih, Jeftlek, Haifa), two samples from Tubas and Aqaba, one sample from factory Agri Plant–Dura, one sample from Palestinian Agricultural Relief Committees (PARC)–Jenin, one sample from Palestinian Agricultural Relief Committees (PARC)–Wadi Fukin, and three Israeli samples (Green Grass, Jenas, and Israeli), and six samples were selected from the Palestinian farmers but originated from Israeli sources. The samples were tested in the Palestinian National Agricultural Research Centre (NARC) Laboratories based in Qabatiya-Jenin. Since the compost is produced using animal manure and other agricultural waste, the absence of heavy metals was expected; therefore, the focus was on physical and chemical parameters, and the heavy metals analysis were considered for six samples only originated from Israeli sources.

The qualitative data associated with the attitudes of agricultural use of compost was collected via a structured questionnaire. The questionnaire included information about socio-economic status of the farmers, the agricultural land, compost use, compost production, and other information regarding the perception of compost benefits compared to other chemical fertilizers. The questionnaire was completed through private interviews with the farmers.

### Data analysis

The analysis of the data was carried out using Microsoft excel and the Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, USA), version 20. Simple frequency tests were utilized for general statistics of the study sample. In addition, a Logistic Regression Model (LRM) was developed to estimate significant effects of the explanatory variables as per (Begum et al. 2006, 2009; Al-Sari et al. 2011; Ali et al. 2012; Ittiravivongs 2012; Al-Khateeb et al. 2017). The explanatory variables in the LRM are as shown in Table 1. The LRM used is as follows:

$$Log\frac{P_i}{1-P_i} = Z_i = \beta_0 + \beta_i X_i + e \quad (1)$$

where $P_i$ is the farmer's attitude to the use of compost in agriculture, $Pi = 1$ if the farmer's attitude to use of compost in agriculture is positive, and $P_i = 0$ if not, $X_i$ = the independent (explanatory) variable (see Table 1), $\beta_o$ = a constant term, $\beta_i$ = a coefficient of the independent variable, $e$ = the error term, and $i = 1, 2 \ldots, n$ which is the number of the independent variables in the model. The direction of the relationship between the dependent variable $P_i$ and the independent variable $X_i$ is determined by the sign of the coefficient $\beta_i$.

Coefficients in the LRM are estimated by the maximum likelihood method. The probability of a certain event occurring was estimated by a logistic regression model through calculating the changes in the logarithm of the dependent variable. The likelihood function as defined in Eq. (2) expresses the values of $\beta$ in terms of known and fixed values of $y$ ($\beta$ is related to $P$) and is derived from the probability distribution of the dependent variable so that the values of $\beta$ that maximize the output of Eq. (2) are the maximum likelihood estimates (Begum et al. 2009).

$$L\left(\frac{\beta}{y}\right) = \prod_{i=1}^{N} \frac{n_i!}{y_i!(n_i-y_i)!} P_i^{y_i} (1-P_i)^{(n_i-y_i)} \quad (2)$$

The statistical significance of each coefficient is evaluated using the Wald test (Begum et al. 2009).

$$W_i = \left(\frac{\beta_i}{S.E_{\beta_i}}\right)^2 \quad (3)$$

where $i = 1, 2 \ldots, n$ and $S.E.$ = standard error.

The model was evaluated using four different tests: the log-likelihood function, the omnibus test, Cox and Snell $R^2$, and Naglekerke $\check{R}^2$ (Al-Sari et al. 2011). The log-likelihood function is used to measure the goodness of fit and is defined as presented in Eq. (4) (Begum et al. 2009).

$$\mathit{Log{-}likelihood} = \sum_{i=1}^{n} \left[ Y_i \ln\left(\hat{Y}_i\right) + (1-Y_i)\ln\left(1-\hat{Y}_i\right) \right] \quad (4)$$

where $Y_i$ = the actual result and $\hat{Y}_i$ = the predicted probabilities of this result. This is also quoted as 2log-likelihood because it has an approximate chi-squared distribution. The Omnibus test, which is a likelihood-ratio chi-squared test, indicates the goodness of fit if the coefficients of the variables in the model are all jointly equal to zero. Cox and Snell $R^2$ and Nagelkerke $\check{R}^2$ are indicating the proportion of the variation in the dependent variable explained by the independent variable of the model. Since Cox and Snell $R^2$ cannot achieve a maximum value of 1, Nagelkerke $\check{R}^2$, which is an adjusted version of the Cox and Snell $R^2$ and covers a full range from 0 to1, is used because it is often preferred (Bewick et al. 2005).

In addition, a correlation matrix of the variables for the model was studied to insure no multicolinearity occurrence, which means no two independent variables have a correlation in excess of 0.7.

## Results and discussion

### Compost quality

Several compost samples were selected from the Palestinian market and from different sources including Palestinian and Israeli sources. The raw materials used for compost in Palestinian sources are animal manure and agricultural waste, while the Israeli sources are unknown. The quality is evaluated based on a set of physical and chemical parameters as shown in Table 2. The heavy metals analysis was conducted in this research for compost samples obtained from Israeli sources only as the Israeli compost facilities are using sludge from wastewater treatment plants, and organic fraction of municipal solid waste that increase the potential for heavy metals existence in the compost. For municipal solid waste, heavy metal content is one of the most controversial aspects in compost quality and it has been widely studied (Barrena et al. 2014).The results of heavy metals analysis are shown in Table 3.

In accordance with the Palestinian standard specification, there is no limitation on some quality parameters. For this reason, these parameters are compared with the Jordanian technical specification for compost production, as Jordan is the nearest country of almost similar soil and weather conditions. The Jordanian standards (JS) issued by the Jordanian Standard Institution (Jordanian Standard Institution (JSI) 2000) specify that ($N_{\mathrm{total}} \geq 1.5\%$), (C/$N \leq$ 1:15), (Moisture content $\leq$ 12%), (organic matter $\geq$60%), (EC $\leq$ 15 dS/cm), and (pH $\leq$ 7.5). Other parameters not specified by the Jordanian standard were compared with other international guidelines and recommended experts' values.

*pH* The 85.7% of the tested samples comply with the Palestinian standard, and 50% only of the tested samples comply with the JS. Samples obtained from Thinnaba, Nasrih, and Jeftlek showed high pH values, and the highest is recorded at Thinnaba, whereas Mothalath and Green Grass showed lower pH (Table 2). pH values are neutral in the compost samples (Quasmeh, Haifa, Garden Bio, Dura, Green Grass) and slightly alkaline in the samples from Thinnaba, An-Nasrih, Jeftlek, and Tubas compost, whereas the Al-Mothalath compost was slightly acidic.

*Organic matter (OM)* The 71.4% of the tested samples comply with the Palestinian standards. None of the tested samples comply with the JS as the highest value is 56% recorded for Thinnaba. In comparison with the United States Composting Council (2001), 42.3% of the samples only comply with these guidelines that require OM of range (30–70%). Two of the tested samples of Wadi Fukin and An-Nasrih recorded very low OM content of (5.74%) and (9.8%), respectively.

*Total nitrogen* The total Kjeldahl nitrogen ($N_{\mathrm{total}}$) provides estimates of possible nitrogen available. The nitrogen contents were larger in the Thinnaba compost than in other samples. $N_{\mathrm{total}}$ content was found to be over 1%, dry weight for 71.4% of the samples. However, four samples of Wadi Fukin, Dura, Garden Bio/Israel, and Gennass/Israel recorded less than 1% of $N_{\mathrm{total}}$.

*Available nitrogen as $NO_{3}$-$N$* The concentration of $NO_3$-N in the Jeftlek compost sample has the highest value (28.6 ppm) and the lowest (20.2 ppm) for Haifa/Israel. All of the samples are above the recommended lower

**Table 2** Physical and chemical quality parameters of the compost in the Palestinian market

| No. | pH | EC, dS/m | Cl, ppm | Ca, ppm | Mg, ppm | $PO_4$, ppm | Na, ppm | K, ppm | OM, % | $NO_3$, ppm | T-N, ppm | C/N, % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.10 | 15.80 | 351.5 | 30.3 | 9.7 | 240.0 | 2600 | 4440 | 27.00 | – | 23,000 | – |
| 2 | 8.88 | 9.50 | 533.0 | 440.0 | 336.0 | 2961.8 | 800 | 6175 | 56.40 | 27.9 | 26,000 | 12.69 |
| 3 | 7.12 | 14.30 | 1633.0 | 385.0 | 366.0 | 2048.3 | 1650 | 5250 | 42.60 | 23.2 | 15,000 | 16.80 |
| 4 | 7.80 | 2.40 | 382.3. | 320.0 | 1344.0 | 1354.9 | 500 | 6000 | 5.74 | 27 | 5500 | – |
| 5 | 7.25 | 10.12 | 665.50 | 160.0 | 336.0 | 1661.3 | 2000 | 12,000 | 26.60 | 27.3 | 800 | – |
| 6 | 8.10 | 7.70 | 3479.0 | 6000.0 | 96.0 | 32.8 | 750 | 1250 | 32.30 | – | 20,000 | 9.00 |
| 7 | 7.80 | 7.20 | 3195.0 | 400.0 | 72.0 | 32.5 | 220 | 635 | 27.80 | – | 14,000 | 11.00 |
| 8 | 6.56 | 13.90 | 433.0 | 1100.0 | 792.0 | 2518.9 | 625 | 4325 | 30.80 | 27.6 | 15,000 | 11.71 |
| 9 | 7.18 | 4.60 | 327.0 | 770.0 | 492.0 | 2491.2 | 400 | 1250 | 23.60 | 20.2 | 22,000 | 6.30 |
| 10 | 7.16 | 3.95 | 332.8 | 200.0 | 528.0 | 1633.6 | 600 | 18,000 | 32.10 | 27.0 | 3640 | – |
| 11 | 6.97 | 9.10 | 99.1 | 80.0 | 240.0 | 1737.5 | 2000 | 8000 | 31.36 | 26.0 | 17,150 | – |
| 12 | 7.95 | 6.59 | 141.6 | 440.0 | 168.0 | 1406.4 | 1200 | 4000 | 21.90 | 26.5 | 4200 | – |
| 13 | 8.56 | 7.00 | 426.0 | 330.0 | 204.0 | 1882.2 | 575 | 4325 | 9.80 | 24.9 | 14,000 | 4.00 |
| 14 | 8.18 | 11.30 | 746.0 | 220.0 | 168.0 | 2297.4 | 875 | 4825 | 21.60 | 28.6 | 15,000 | 8.40 |
| Avg | 7.6 | 8.8 | 951.0 | 776.8 | 368.0 | 1592.8 | 1056.8 | 5748.2 | 27.8 | 26.0 | 13,949.3 | 10.0 |
| Max | 8.88 | 15.8 | 3479 | 6000 | 1344 | 2961.8 | 2600 | 18,000 | 56.4 | 28.6 | 26,000 | 16.8 |
| Min | 6.56 | 2.4 | 99.1 | 30.3 | 9.7 | 32.5 | 220 | 635 | 5.74 | 20.2 | 800 | 4 |
| SD | 0.67 | 4.00 | 1127.14 | 1528.77 | 349.58 | 925.85 | 722.98 | 4566.09 | 12.41 | 2.44 | 7784.33 | 3.98 |
| PSI[a] | 5-8.5 | $\leq 4^b$ | NS | NS | NS | NS | [c] | [c] | > 25% | NS | [c] | [d] |
| Accuracy | ± 0.01 | ± 0.01 | ± 1 | ± 0.10 | ± 0.10 | ± 0.10 | ± 5.01 | ± 5.011 | – | ± 0.12 | ± 5.02 | – |

Source of samples: (1) PARC, (2)Thinnaba, (3) Quasmeh, (4) WadiFukin, (5) Dura, (6) Tubas, (7) Aqaba, (8) Mothalath (Israel), (9) Haifa (Israel), (10) Garden Bio (Israel), (11) Green Grass, (12) Gennass (Israel), (13) An-Nasrih, and (14) Jeftlek

*NS* not specified

[a] For application below the surface of 5 cm, and no limits for application at depth of 20 cm below the surface. In both cases, there are limits on the quantities of compost to be applied per dunum

[b] As announced by the producer ± 25%

[c] As announced by the producer

[a] From Palestinian Standards Institution (PSI) 2012

and upper threshold if compared to Qadomi (2014), who reported the favorite $NO_3$-N content to be in the range of 20–150 ppm.

*C/N ratio* All of the tested samples are found to comply with the JS, and the average was found to be (10.00 ± 3.98). In comparison with other studies, Vázquez and Soto (2017) found that the average C/N ratio for home composting is (12.8 ± 3.5). The highest C/N ratio is recorded at 16.80% for Quasmeh, and lowest is recorded at An-Nasreh of 4.00%.The C/N ratio values comply with the US EPA recommended upper limit of 25 ppm. The C/N ratio decreases throughout the composting process, which indicates the stability of the compost (Sánchez-Monedero et al. 2002).Usually, composting process can be regarded as finished when a C/N of 17 or less is reached (Woods End Research Laboratory 2005).The low C/N ratios for the tested samples indicated that the compost in the Palestinian market is stable.

*EC* It indicated the amount of salts in soil, as the electrical conductivity increases as the percentage of soluble salts increases. The main ions contributing to salinity are sulfate, nitrate, ammonia, chloride, potassium, and sodium. Almost all of the tested samples comply with the JS except those samples obtained from PARC (15.8 dS/m).

*$PO_4$-P* The average of the $PO_4$-P content of the 14 samples was calculated to be (1592.8 ppm). Based on the end-use recommended values of USA, which is in the range between 800 and 2500 mg/l as reported by Wood End Research Laboratory (Wood End Research

**Table 3** Heavy metal parameters of the compost in the Palestinian market

| Sample no. | Results (mg/kg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pb | Mn | Cr | Co | Ni | Cd | Zn |
| 1 | 33.00 | 357.00 | 46.75 | 65.00 | 24.78 | 13.75 | 390.25 |
| 2 | 44.25 | 318.50 | 81.50 | 67.50 | 14.55 | 17.50 | 362.75 |
| 3 | 48.75 | 362.25 | 66.00 | 69.00 | 24.40 | 19.00 | 351.00 |
| 4 | 35.00 | 292.50 | 58.25 | 64.75 | 22.88 | 17.50 | 388.25 |
| 5 | 30.25 | 306.00 | 56.25 | 54.23 | 14.08 | 21.00 | 379.00 |
| 6 | 36.75 | 305.50 | 48.75 | 56.00 | 21.48 | 23.00 | 288.25 |
| Average | 38.00 | 323.63 | 59.58 | 62.75 | 20.36 | 18.63 | 359.92 |
| Max | 48.75 | 362.25 | 81.50 | 69.00 | 24.78 | 23.00 | 390.25 |
| Min | 30.25 | 292.50 | 46.75 | 54.23 | 14.08 | 13.75 | 288.25 |
| SD | 7.07 | 29.12 | 12.78 | 6.15 | 4.83 | 3.20 | 38.24 |
| PSI[a] | 300 | NS | 400 | NS | 90 | 20 | 2500 |
| Accuracy | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

[a] From Palestinian Standards Institution (PSI) 2012

*NS* not specified

Laboratory 2000), only 14.3% of the tested samples did not comply with this guideline.

*Potassium (K)* All of the tested samples show the potassium value in the range of (635–18,000) ppm and an average value of 5748.2 ppm. If compared with recommended values of USA (500–2000) mg/l (Wood End Research Laboratory 2000), only 21.4% of the samples meet this guideline.

For magnesium (Mg) and calcium (Ca), there are no limits provided by neither the Palestinian standards nor the JS. The test result presented in ppm for those cations is difficult to be compared by other standards or recommended values because this is too broad rating and usually not specific enough to truly determine the media characteristics (Compost Management Program 2005).

*Chloride (Cl)* The results showed that the Cl values are in the range of (99.1–3479.0) ppm, and an average value of (951.0) ppm. In reference to German standards as reported by the Waste and Resources Action Programme (The Waste and Resources Action Programme (WRAP) 2002), type 2 compost (Cl < 1000 mg/l), only 21.4% of the samples did not meet this specification.

*Sodium (Na)* The average sodium content is (1056.8 ppm), and all the values are in the range of (220.0–2600.0) ppm. If compared to the German standards as reported by the Waste and Resources Action Programme (The Waste and Resources Action Programme (WRAP) 2002), type 2 compost (Na < 500 mg/l), only 64.3% of the samples did not meet this specification.

The results of heavy metals analysis conducted on compost samples obtained from Palestinian market, but originated from Israeli sources, showed that all of the samples meet the PSI standards except samples number 5 (21.0 mg/kg) and 6 (23.0 mg/kg) which exceeds the *cadmium* (*Cd*) limit. However, both samples comply with some European countries standards like Spain for max concentration limit of 40.0 mg/kg (Wood End Research Laboratory 2000).

Based on the above-mentioned, and in accordance with the Palestinian standards for organic fertilizers, there is little deviation from the specified limits. These deviations could be attributed to improper treatment during the composting process, and/or the quality of the row materials used for compost production. In general, exceeding the upper threshold of the standard could result in environmental and health risks. However, the deviation from the Palestinian standard is little and its impact could be minimal. An additional effort is needed to improve the quality of compost and specially reducing the salts that link to the electric conductivity.

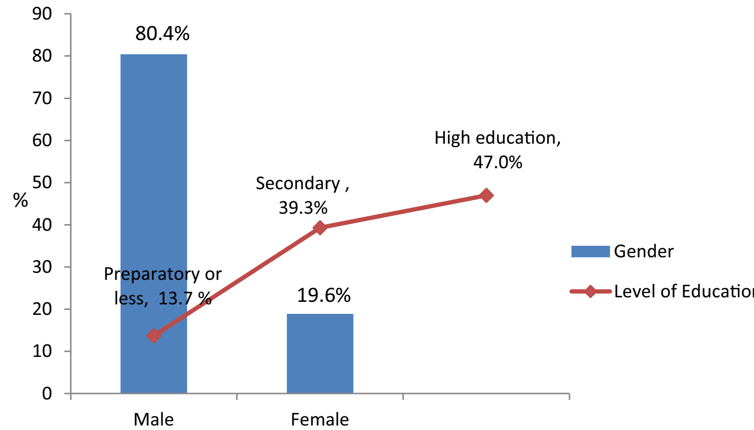


**Fig. 3** Level of education and gender of the surveyed farmers

## Attitude toward use of compost in agriculture

The level of education and gender of the surveyed farmers are shown in Fig. 3. The study sample composed of about80.0% men and 20.0% women of different levels of education as shown in Fig. 3.

The farmers' attitude to the use of compost in agriculture showed that generally the Palestinian farmers have positive attitude since 91.2% of the farmers have the desire to use compost in agriculture, while only 8.8% of the surveyed farmers do not have the desire to use compost in agriculture.

## Factors affecting farmers' attitude

Several factors were selected to evaluate their influence on the farmers' attitude to compost use for agriculture. These include the farmer income, number of types of plants he/she grows, area of the agricultural land he/she uses, annual cost of compost he/she currently use, knowledge of difference between compost and chemical fertilizers, whether the farmer previously used compost or not, knowledge and awareness that compost can resist plant diseases, perception of the benefits of compost, and whether the farmer previously faced problems of using compost. The factors affecting the farmers' attitude are estimated using Eq. (1) as follows:

Logit (farmer attitude) = − 8.544 − 0.549 X1 + 0.480 X2 − 0.046 X3 − 0.003X4 + 5.551 X5 + 0.970 X6 + 2.272 X7 + 1.393 X8 − 3.476 X9.

The results showed that three out of nine selected factors can significantly influence the farmers' attitude toward the use of compost as organic fertilizers in agriculture. These include knowledge of difference between compost and chemical fertilizers, and perception of compost benefits, previously experiencing problems in

**Table 4** LRM output of attitude toward compost use in agriculture

| Variable | Abbreviation | Estimated coefficient (β) | Standard error (SE) | Wald statistics | *df* | Significance (*P* value) |
|---|---|---|---|---|---|---|
| $X_1$ | Income | − 0.549 | 0.662 | 0.689 | 1 | 0.407 |
| $X_2$ | Plants | 0.480 | 0.658 | 0.532 | 1 | 0.466 |
| $X_3$ | Agri. land area | − 0.046 | 0.130 | 0.124 | 1 | 0.725 |
| $X_4$ | Comp. cost | − 0.003 | 0.002 | 1.654 | 1 | 0.198 |
| $X_5$ | Comp. vs. chemical | 5.551 | 2.372 | 5.475 | 1 | 0.019* |
| $X_6$ | Previous use | 0.970 | 1.164 | 0.695 | 1 | 0.404 |
| $X_7$ | Comp. resist disease | 2.272 | 1.770 | 1.648 | 1 | 0.199 |
| $X_8$ | Benefits perception | 1.393 | 0.691 | 4.067 | 1 | 0.044* |
| $X_9$ | Previous problems | − 3.476 | 1.645 | 4.464 | 1 | 0.035* |
| Constant | | − 8.544 | 4.471 | 3.652 | 1 | 0.056 |

*Significant at $P \leq 0.05$

**Table 5** Model summary and goodness-of-fit tests

| Test | Results | | |
|---|---|---|---|
| | −2 Log likelihood | Cox and Snell $R^2$ | Nagelkerke $R^2$ |
| Model summary | 26.181 | 0.241 | 0.505 |
| | Chi-square | *df* | Sig. |
| Omnibus tests of model coefficients | 19.330 | 9 | 0.023 |

compost use. The results revel that farmers who believe that compost is better than chemical fertilizers showed lower attitude toward compost use; farmers who are more familiar with compost benefits showed more positive attitude toward compost use, and farmers who had previously experienced problems in compost use showed more positive attitude to the use of compost in agriculture. Although the latter is confusing, this could be attributed to the fact that the farmers are aware of the benefits of compost, but they faced problems in the past due to bad quality of compost available in the market at that time. However, it is believed they have the interest to use compost in the case of good quality.

The influence of other factors is as follows:

– Income: farmers of high income showed less attitude toward compost use.
– Type of plants: farmers who grow different types of plants showed more positive attitude toward compost use. The larger is the number of plants grown, the more positive is the attitude. This could be attributed to the fact that the larger is the number of plants, the larger is the quantity of fertilizers needed, and compost is cheaper than chemical fertilizers.
– Area of agricultural land: the larger is the area of the agricultural land the farmer owned, the lower is the attitude toward use of compost.
– Compost cost: farmers who are currently paying more showed less attitude toward compost use. Nassar et al. (2009) found that in average, farmers who use sludge as organic fertilizers in Gaza Strip are willing to pay more for organic fertilizers than farmers who did not use sludge.
– Previous use: farmers who previously have not used compost showed more positive attitude. Somda et al. (2002) found that older farmers are less likely than younger ones to adopt compost in agriculture. Farmers in the Gaza Strip/Palestine who have not used sludge as organic fertilizers have the willingness to use it in agriculture if it is treated well and shows good results after application (Nassar et al. 2009). Danso et al. (2002) reported that majority of the farmers are willing to use and pay for compost, often without related prior experience.
– Farmers who do not have the knowledge that compost can resist plant diseases showed more positive attitude.

The developed LRM fits the data well. The results of the LRM and the goodness-of-fit data are shown in Tables 4 and 5, respectively.

## Conclusions and recommendations

Compost quality of the Palestinian market is studied through random selection of samples provided by different suppliers, Israeli and Palestinian produces. Due to the absence of limitations on some quality parameters by Palestinian standards for compost, the values of these tested parameters have been compared to the Jordanian Standards (JS) and other international specifications and guidelines for parameters not provided by the JS. The results have showed that the compost in the Palestinian market could be classified by medium quality due to partial or non-compliance with some of the testing parameters.

The results have showed that the farmers' attitude to agricultural use of compost is generally positive. It has been found that knowledge of difference between compost and chemical fertilizers, perception of compost benefits, and previously experiencing problems in compost use are significant factors affecting the farmers' attitude toward use of compost as organic fertilizer in accordance with Eq. (1).

Improving the quality of the compost products is of high importance in order to meet the standard specifications and guidelines to insure proper environmental protection. In addition, it is recommended to promote the use of compost in agriculture and encourage its use through subsidies due to the current economic status in Palestine, although compost cost is identified as insignificance but farmers who paid more showed less attitude toward the use of compost.

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