Original scientific paper
10.7251/AGRENG1703099S
UDC: 628.473.3:634.8(569.3)

USE OF LOCAL COMPOSTED WINERY WASTE FOR LETTUCE PRODUCTION IN LEBANON

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ABSTRACT

Recently, the Lebanese wine sector has been witnessing a non-precedent growth producing huge amounts of winery wastes referred to as grape marc. The effect of using grape marc compost on lettuce (*Lactuca sativa* L.) production was investigated in an open-field experiment in Central Bekaa. Seedlings of the Romaine variety were planted in different substrates: S1: 100% soil or control, S2: 75%soil + 25% grape marc compost, S3: 25%soil + 75% grape marc compost and S4: 100% grape marc compost. Root growth, leaf growth and leaf characteristics were compared among the different mixtures. Tests showed that the grape marc compost contained acceptable values of nitrogen, phosphorus, potassium, organic matter and a perfect germination index ranking between 0.8 and 1 for the direct and diluted solutions. Results showed that at early stages of growth, the best results were obtained from plants grown in the substrate S4. However, at later stages of growth, grape marc compost with a percentage higher than 50% (S4) in the mixture induced lower averages of leaf number, length and width of largest leaf and leaf weight and those higher than 25% (S3 and S4) increased dry matter and total soluble solids content due to its low water holding capacity causing a water stress on plants. Root growth was proportional to increased percentages of grape marc compost. Finally, composted grape marc provided the highest benefit to plants when added to soil in quantities of 25% by volume allowing the best yield increase (47%) compared to control.

Keywords: *Lactuca sativa*, grape marc compost, water holding capacity, plant growth.

INTRODUCTION

Winemaking industries are an important part of the economy in many parts of the world. Grape processing for winemaking results in large amounts of solid wastes

normally referred to as grape marc or pomace formed by pressed skins (about 70-80%), stems (10%), seeds (8%), stalks (2.5-7.5%) and pulp (57%) (Jiang *et al.*, 2010). The grape marc is the main by-product of the wine industry. It is a cheap product widely distributed in the Mediterranean area (Scettrini and Jelmini, 2004). Grape marc is rich in macro and micro-nutrients, nitrogen, potassium and phosphorus and is valued for its organic matter content (Eleonora *et al.*, 2014). It can be used as a crop fertilizer (Pinamonti *et al.*, 1997), however its direct application of grape marc to soil can have negative effects on the environment (Deng *et al*., 2011), thus it is applied in a composted form (Gazeau, 2012).
The main aspects studied for grape wastes are related to their physical, chemical and microbiological characteristics developed during composting (Ferrer *et al.*, 2001) which vary depending on the grape variety, season, harvest method and pressing method during processing (White, 2008). The use of composted grape marc has shown many advantages; its application to soil increased nutrients, organic matter content and microbial biomass (Arvanitoyannis *et al.*, 2006). It was successfully used in horticulture due to its physico-chemical properties (Ferrer *et al.*, 2001) like pH, C/N ratio and moisture content (Stafne and Carroll, 2008). It also improved soil properties thus could be used as soil conditioner. It does not cause problems of high salinity compared to many other types of organic compost, however it has a high drainage (58%) which can cause problems of plant mortality due to drying out of roots (Scettrini and Jelmini, 2004). Literature has reflected a positive influence of using composted winery wastes on many crops like tomato, melon (D'Addabo *et al.*, 2000), corn (Ferrer *et al.*, 2001), mushroom (Pardo *et al.*, 2007), onion (Stafne and Carroll, 2008), and on ornamental plants (Carmona *et al.*, 2012). Also, grape marc compost could partially substitute peat without causing any loss in yield and in the nutritional status of lettuce seedlings (Bustamante *et al.*, 2008) and when mixed with peat it produced good results for lettuce seedlings production (Carmona *et al.*, 2003). The production of grape marc compost is widespread in Lebanon where large amounts of wastes are produced from winemaking. There is little knowledge about the potential use of locally available winery wastes in vegetable production in Lebanon, consequently this experiment investigated the effect of grape marc compost application to soil on lettuce crop which is a valuable crop widely grown under greenhouse and open-field conditions in Lebanon.

MATERIALS AND METHODS

The experiment was carried out in spring 2014 in an open field located in Central Bekaa-Lebanon. Soil tests indicated that it was a silt-clay, rich in calcium, poor in organic matter and with acceptable values of nitrogen, potassium and phosphorus and nematode-free. Moreover, grape marc compost was provided by a local winery. Physical and chemical properties of this by-product were tested and they revealed that it was alkaline (pH=7.1), rich in organic matter (81.6%), nitrogen (3.2%) and potassium (3.08%) with a C/N ratio of 13.9. Micronutrients and heavy metals content in this compost were within the acceptable levels of application to agricultural soils. A phytotoxicity test was performed on the composted grape marc using germination and root elongation tests on *Lepidium sativum* seeds (Zucconi *et al.,* 1981). Results for the three rates of dilution (0X, 3X and 10X) registered a germination index ranking between 0.8 and 1.0. Consequently, the substrate could be used with or without dilution.

Lettuce seedlings of the variety Dark Green Romaine (*Lactuca sativa* L. var. *longifolia*) were transplanted in 5 April into tunnels that were dug in the experimental field and filled by 4 different types of substrates: S1: 100% soil, S2: 75% soil + 25% composted grape marc, S3: 25% soil + 75% composted grape marc, and S4: 100% composted grape marc. The experimental design was a Randomized Complete Block Design (RCBD) with 3 replications per treatment and 50 plants per replication. Irrigation was done at an interval of 5 days using GR drip system after crop water requirements were deduced from cropwat 8.0 software.

Data recording

Data was collected 20 days after transplanting (date 1: rosette stage), 40 days after transplanting (date 2: head formation stage) and 63 days after transplanting (date 3: at harvest) on 5 plants chosen randomly from each plot. Investigated parameters were: length of main root, root neck diameter, number of secondary roots, number of leaves, length and width of leaves, weight of heads and root weight. Further tests were performed at the date of harvest such as Total Soluble Solids (TSS) content that was determined on the liquid extract of plant leaves using an Atago N1 refractometer. In addition, dry matter (DM) content was determined on lettuce heads oven dried at 70◦C for 48 h. Dried heads were then ground to a fine powder using a mill with 0.5mm for measuring the nitrogen (N) content (micro-Kjeldhal digestion procedure), phosphorus (P) content (Vanadate-Molybdate-Yellow method), potassium (K) content (flame photometer) and Zn, Cu, Pb, Cd, Fe and Mn content (atomic absorption spectroscopy).

Statistical analysis

Data analysis was done using Sigma Stat 3.2 Software. Multiple mean comparisons were done using the ANOVA test and Tukey tests as ranking tests depending on data distribution.

RESULTS AND DISCUSSION

Plant growth was affected differently by the substrate type. Results showed that at the rosette stage (Table 1) plant growth was positively affected by an increased proportion of composted grape marc in the substrate. The highest averages were reached in the substrate S4 for all measured parameters. In general, a better elongation of main roots was combined with a higher percentage of grape marc compost in the substrate. This was translated by a significant difference in average length of main roots that was of 13.06 cm, 13.46cm, 14.14 cm and 15.12 cm in S1, S2, S3 and S4 respectively. Moreover, average values of the majority of parameters were significantly higher in S3 compared to S2 except the number of secondary roots and weight of heads that did not differ significantly between both substrates.

At the stage of head formation (Table 2) root parameters such as length of main root, number of secondary roots and total weight of roots recorded the highest averages in the substrate S4. The average root neck diameter did not differ significantly between the substrates S2, S3, and S4 while it was significantly higher in those three substrates compared to S1. At this developmental stage, root growth would be proportional to the proportion of compost in the growing medium. On the other hand, average number of leaves, average width of largest leaf, average length of the largest leaf and average weight of heads did not differ significantly between the treatments S2 and S3, however they were significantly higher in both substrates compared to S1 and S4 with the lowest values recorded for S1.

At harvest (Table 3), in the substrate S4 mature plants had developed the longest main roots (average length of main root in S4: 27.62cm compared to S1: 19.26cm, S2: 20.23cm and S3: 24.94cm), the heaviest root system (average weight of roots in S4: 47.09g compared to S1: 43.18g, S2: 42.92g, and S3:45.6g) and most ramified root system with the highest number of secondary roots (S4: 175.6 compared to S1: 149.8, S2: 150.4 and S3: 162.6). The average root neck diameter was almost the same in all substrate types.

Leaf development (average leaf number, average leaf length and average leaf width) was the best in S2. Also at this stage, there was no significant difference in average weight of heads in S2 and S3; however both substrates allowed the formation of heavier heads when compared to S1 and S4. Consequently, in S2 yields were improved by 47% and in S3 by 28% compared to control.

Table 1. Means and standard deviations of roots and heads parameters measured at the rosette stage

Substrate	Length of main root (cm)	Root neck diameter (cm)	Number of secondary roots	Number of leaves	Width of largest leaf (cm)	Length of largest leaf (cm)	Weight of rosette leaves (g)	Weight of roots (g)
S1	13.06±0.3d	2.0±0.2d	70.6±3.65bc	24±1.58d	7.76±0.11d	14.72±0.25d	210.6±9.73bc	18.59±0.27d
S2	13.46±0.3c	2.48±0.15c	83.6±2.41abc	26.4±2.07c	8.28±0.08c	15.56±0.11c	251± 2.53abc	20.49±0.31c
S3	14.14±0.2b	2.7± 0.1b	87.6±1.14ab	29.42±1.14b	8.82±0.08b	16±0.10b	281.4±2.37ab	21.48±0.25b
S4	15.12±0.4a	3.0±0.16a	95±3.54a	32.4±1.14a	9.58±0.15a	16.5± 0.16a	297.6± 2.13a	23.43±0.16a
Test 5%	Annova	Annova	Tukey test	Annova	Annova	Annova	Tukey test	Annova

Numbers followed by different letters are significantly different

Table 2. Means and standard deviations of roots and heads parameters measured at stage of head formation

Substrate	Length of main root (cm)	Root neck diameter (cm)	Number of secondary roots	Number of leaves	Width of largest leaf (cm)	Length of largest leaf (cm)	Weight of heads (g)	Weight of roots (g)
S1	15.34±0.18d	2.26±0.11b	105±6.17d	37.8±1.09c	11.3±0.52b	20.62±0.26c	433.37± 7.23b	30.39±1.29d
S2	16.9±0.19c	2.64±0.11a	128.1±3.21c	46±0.71a	12.7±0.4a	23.84±0.45a	678.04±96.04a	33.42±0.78c
S3	20.96±0.69b	2.56±0.11a	137.8±3.42b	52.6±1.14a	13.16±0.15a	24.46±0.79a	662.92± 12.4a	37.34±0.76b
S4	24.94±0.27a	2.62±0.31a	163.8±3.77a	40.2±0.84b	11.6±0.16b	21.96±0.24b	441.64±21.87b	42.66±1.19a
Test 5%	Annova	Annova	Annova	Annova	Annova	Annova	Annova	Annova

Numbers followed by different letters are significantly different

Table 3. Means and standard deviations of roots and heads parameters measured at the harvest stage

Substrate	Length of main root (cm)	Root neck diameter (cm)	Number of secondary roots	Number of leaves	Width of largest leaf (cm)	Length of largest leaf (cm)	Weight of heads (g)	Weight of roots (g)
S1	19.26±0.35d	2.64± 0.055	149.8±2.49c	74.8±1.3bc	13.18±0.84c	27.1±0.32c	676.2±7.59b	43.18±0.55c
S2	20.23±0.08c	2.94±0.089	150.4±2.07c	88.8±1.9a	16.7±0.34a	33.82±0.45a	994.78±21.11a	42.92±0.22c
S3	24.94±0.52b	2.8±0.16	162.6±6.35b	79.8± 0.8b	14.88±0.15b	29.28±0.28b	865.1± 15.55a	45.6±0.49b
S4	27.62±0.59a	2.62±0.31	175.6±3.78a	59.8± 4.0c	12.04±0.49d	23.46±0.35d	605.06±10.19b	47.09±0.51a
Test 5%	Annova	Annova	Tukey test	Annova	Annova	Annova	Tukey test	Annova

Numbers followed by different letters are significantly different

The effect of grape marc compost differed between growth stages. It was less evident at the rosette stage, however at later stages differences in all parameters related to head formation were more obvious where all substrates containing grape marc compost induced the formation of heavier heads with more abundant, longer and wider leaves compared to soil (Figure 1). At the stage of head formation, the substrates S2 and S3 marked the formation of best lettuce heads, while at harvest the heaviest and best developed heads were obtained in S2. Therefore, a rate of 25% of grape marc compost in the substrate was enough to induce amelioration of harvested lettuce heads.

It seemed that the use of grape marc compost has negatively affected water availability to plants because of the low water holding capacity of this substrate which caused water-stress conditions. The best crop performance that was obtained in S2 could be due to the better maintenance of internal balance by plants and the improved utilization of water and nutrients. When soil moisture deficit increases the rate of water absorption decreases, thus water deficit reduces leaf area and cell size in the whole vegetative part (Ramalan and Nwokeocha 2000). Grape marc compost has helped plant roots to explore a larger area of soil, thus it enhanced water and nutrient absorption. Lettuce appreciates a soil rich enough in organic matter (Weill and Duvall, 2009), but it requires also a well-structured, well-drained and well-aerated to provide a good growth of roots (Collin and Lizot, 2003).

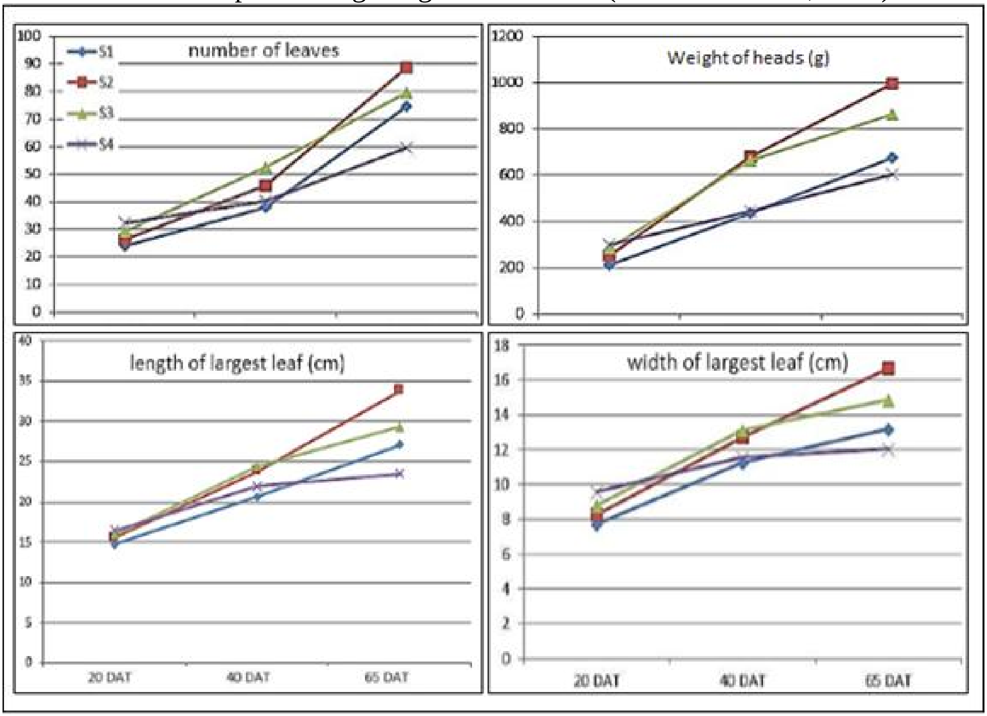

Figure 1. Evolution of head parameters as affected by the four different types of substrates

Adding grape marc compost has enhanced the nutritional importance by increasing macronutrients, dry matter and total soluble solids in lettuce leaves. N, P, K content in lettuce plants was higher in S2, S3 and S4 compared to S1 (Table 4). Nitrogen content was very close in S3 and S4 with 3.66 $mg.Kg^{-1}$ and S4: 3.67 $mg.Kg^{-1}$ respectively. Same tendency was observed for phosphorus and potassium. The high drainage of grape marc compost has caused a water stress on lettuce plants, therefore the accumulation of assimilates was greater in plant leaves. There was amelioration in DM and TSS content correlated with an increase of compost percentage. Superiority of dry matter accumulation and sugar content was for the substrate S4.

Table 4. Macronutrients, dry matter and total soluble solids content in harvested lettuce

Substrate	N ($mg.Kg^{-1}$)	P ($mg.Kg^{-1}$)	K($mg.Kg^{-1}$)	D.M (%)	TSS (◦Brix)
S1	1.93	0.357	3.01	5.2	4.4
S2	3.30	0.720	4.6	5.3	4.5
S3	3.66	0.729	4.8	5.8	5.3
S4	3.67	0.793	4.9	6.1	5.7

N: Nitrogen, P: Phosphorus, K: Potassium, D.M: Dry matter, TSS: Total Soluble Solids

Pb and Cd content in lettuce plants remained within the normal ranges indicated by Ross (1994) after addition of composted grape compost to soil. On the other hand, there was an increase in Zn, Cu, Fe, and Mn content in lettuce plants with increased rate of composted grape marc in the substrate (Table 5).

Table 5. Microelements and heavy metals content in harvested lettuce

Substrate	Zn (µg/g)	Cu (µg/g)	Pb (µg/g)	Cd (µg/g)	Fe(µg/g)	Mn(µg/g)
S1	38.68	4.95	8.50	0.425	106.38	10.00
S2	75.35	8.55	9.30	0.500	141.35	47.75
S3	76.03	8.28	9.50	0.525	150.95	58.50
S4	113.85	8.18	9.60	0.525	326.63	158.25

CONCLUSIONS

Composted winery wastes would play a positive role in Lebanese agricultural production. Those widely available wastes could be used in large quantities as a fertilizer providing nutrients to crops and could safely alternate chemical fertilizers in local cultivations. Grape marc compost also confers adequate characteristics for being used as a soil conditioner due to its richness in organic matter and could improve the physical characteristics of heavy soils by improving water drainage. It could provide the highest benefit to plant when added to soil in quantities of 25% by volume. On the economical level, using composted grape marc has a significant advantage shown by the reduction of production costs compared to conventional substrates.

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