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ORIGINAL RESEARCH

Effect of date palm waste compost on forage alfalfa growth, yield, seed yield and minerals uptake

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Abstract
Purpose Date palm (*Phoenix dactylifera* L.) is one of the predominant fruit trees grown in oases ecosystems (Southern Mediterranean regions) and produces several wastes during practicing cultivation since fruit and bunch thinning is frequently applied. Yet, the valorization of date palm wastes as bioresources has received little attention. The main objective for the present research is to assess palm trees compost (P-compost) as organic fertilizer for alfalfa (*Medicago sativa* L.).
Methods The experiment was carried out in an experimental field involving four replicates and three soil amendment treatments (1) control, conventional mineral fertilizer diammonium phosphate, (2) 30 t ha^{-1} of cow manure, and (3) 30 t ha^{-1} of palm tree compost (P-compost). Plots were planted on with alfalfa and the measurements of studied traits (growth, yield, seed yield and minerals uptake) were determined for two crop seasons (2010 and 2011).
Results Compared with untreated soil, the palm compost application at 30 t ha^{-1} improved significantly both organic matter and water retention capacity of the soil and decreased the electrical conductivity (− 70%). Furthermore, palm compost supply significantly increased fresh biomass production of alfalfa by 21 and 28%, respectively, during the first and second seasons. Also, it enhanced the grain yield and growth rate (stem length and leafs expansion) of this species. At the first crop season, the palm compost application had a positive impact on minerals nutrition compared to the control treatment, with improving rates of + 32% for phosphorus, + 25% for potassium and + 6% for nitrogen. In addition, these contents were higher than in plants grown under cow manure amendment. However, at the second season, the palm compost improved only P and N contents.
Conclusions This preliminary finding suggests that palm compost at moderate dose (30 t ha^{-1}) could be highly beneficial for forage plant yield.

Keywords Date palm compost · *Medicago sativa* · Biomass production · Essential minerals

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Introduction

Negative effects are often induced in crop soil quality by application of intense cultivation practices (Batlle-Bayer et al. 2010) such as the excessive usage of chemical fertilizers. Conventional farm systems have been characterized by a high use of chemical fertilizer causing the deterioration of qualitative soil and agricultural production (Diacono and Montemurro 2010; Singh et al. 2007). Also, excessive utilization of this chemical fertilizer with no organic amendments can pollute the surrounding environment due to the excessive leaching of nutrients (Lim et al. 2015b). Consequently, the decrease in soil organic matter could be in cause of the infertility and unproductively of soil induced by a lower microbial activity and infiltration rate (Martin et al. 2010). Therefore, organic amendments and manures have a positive effects and help in the stability of soil fertility and agricultural yields. From the various organic products, compost and livestock manure have been characterized as interesting soil amendment. Commonly, Compost can be produced by composting or/and vermicomposting processes (Lim et al. 2016; Wu et al. 2014). The application of a mixture of manure and biosolids is considered the best practice that is commonly used by farmers (Rigane and Medhioub 2011). Compared to individual fertilizers (such as nitrogen, phosphorus, and potassium), animal manures contribute significantly to the soil fertilization. Also, sustained use of manures can improve organic matter and structure of soils.

Manures from livestock and other traditional farm animals are most familiar to rural farmers. Animal manures from cows, horses and chickens are commonly available and used as fertilizers. Cow manure is most popular in many rural areas in the world than manure from other farm animals. For that, its availability has been significantly decreased in the farm regions due to the decrease of elevated animals themselves. In addition, many difficulties are related to the fertilization by cow manure such as handling, transportation and large amounts required to get the nutrient needs of plants. Therefore, the farmers and researchers are always looking for an alternative organic fertilizer from their natural ecosystem. Consequently, the use of sewage sludge composts or municipal solid waste in the farm has been highly explored by environmental agencies since it provides interesting environmental and economic benefits more than traditional biosolids' management practices (Hargreaves et al. 2008). Nevertheless, potential health and ecological risks can arise as a result of the nutrient transport to ecologically sensitive receptors and accumulation of trace elements in the soil (Pierzynski and Gehl 2005; Smith 2009). These issues need more investigation to diminish the environmental risks and to increase the use of compost in agriculture. Many countries have initiated specific safety instructions. Although the subject is still under debate (Barral and Paradelo 2011) and they are trying to valorize the vegetal compost without external supplements from farm systems.

In North African oases, the crop system is dominated by two species: the date palm (*Phoenix dactylifera* L.) as fruit trees with annual production and the alfalfa (*Medicago sativa* L.) as perennial forage crops. Date palm represents a good cash crop for many farmers (Hamza et al. 2015).The fruit is an ancient cultivated food that is important in Mediterranean, Middle East and other tropical and subtropical areas. Date palm growing and production requires good cultivation practices (Watering, fertilization, spraying, sucker pruning and date-fruit thinning, etc.). Reducing the number of fruits per strand is commonly used and fundamental for enhance fruit size, satisfy market preference and avoid humidity damages (Hamza et al. 2015). The large amounts of palm wastes produced every crop season constitute a big charge for the farmers who are always trying to burn or transport them outside of oasis. Therefore, composting could provide an economical and environmentally significant method to reduce date palm wastes. Study of composting of 70% date palm wastes and 30% shrimp and crab wastes shows that the final compost could be a good fertilizer (57.1% moisture content and an organic matter of 891 g/kg dry matter (Khiyami et al. 2008). Ali (2008) demonstrated that date palm leaves compost increases germination and growth of four ornamental plants (*Cosmos bipinnatus, Dahlia variabilis*, *Tagetes erecta* and *Zinnia elegans*). Mohammadi (2013) reported that date palm wastes have a good potential to be used as culture media for plant growth under hydroponic systems.

Alfalfa, *Fabaceae* family, is one of the most important forage crops worldwide due to its excellent forage quality, high forage yield in many various environments around the world, and high adaptability to diverse climatic conditions (Moreira and Fageria 2010), and has positive effects on soil fertility (Campiglia et al. 1999; Huyghe 2003). In traditional farmers of southern Mediterranean areas, it is cultivated surrounding date palm trees.

The goal of this work was to assess the application of palm trees compost at 30 t ha^{-1} for two consecutive years on soil properties and on alfalfa growth, yield and mineral nutrition. The palm compost usefulness as alternative fertilizer of cow manure is also discussed.

Materials and methods

Experimental design

The experiment was carried out in an open field of Arid Areas Institute situated in the south of Tunisia (33.50N, 10.06E, 16 m a.s.l.) and characterized by a loamy sandy soil. Plots (3 m × 2 m) were established in a split–split plot design with four replicates per treatment. The soil used as a control is a representative soil from the oasis surrounding area and it has been subjected to intense degradation due to severe agricultural practices imposed in the last decades. The climate is Mediterranean arid, with an annual temperature of 18 °C, and an annual average precipitation of 190 mm.

Three soil treatments were applied prior seedling: (1) unamended soil treated with conventional mineral fertilizer diammonium phosphate (control), (2) soil amended with 30 t ha^{-1} of traditional manure (cow manure), and (3) soil amended with 30 t ha^{-1} of palm tree compost (P-compost). The plots were spaced 1.0 m within and between rows, and were irrigated regularly with conventional intervals of 15 days. The manure and compost were mixed in the top 20 cm of soil to simulate the common field conditions. Then alfalfa (*Medicago sativa* L.) seeds were sown on March 2010 and the assessment of alfalfa behavior was assessed for two crop seasons till August 2011.

Date palm composting

Date palm compost was collected from composting station of NGmO*ASOC* (Association for Saving Oasis of Chenini, Gabes, Tunisia). Date palm wastes compost were mechanically produced according to the following steps: (1) collect of palm tree wastes; (2) grinding residues; (3) transmission of ground product to the steeping basins; (4) soaking the ground material in water (7–10 days), (5) drying and mixing with cow manure in a 3:1 ratio; (6) preparation of Andean and fortnightly mixing of amount water and aged 6 months prior to its use to eliminate any potential pathogen. Initial characteristics and mineral concentrations of the date palm compost and cow manure used in this study are shown in Table 1.

Yield and seed yield

Alfalfa (*Medicago sativa L.)* leaves and stems were harvested every 1–2 months and assessed for fresh and dry weights. Plant fresh biomass (BFW) was weighted and dried in an oven at 60 °C for 24 h to determine the dry weight. In the summer of each year, grain yield was determined by keeping plants without harvest up to produce pods and seeds, and then seeds in 1 m^2 were collected and weighted.

Table 1 Characteristics of palm compost and cow manure

Parameter	P-compost (6 months)	Cow manure
pH (H_2O)	7.6 ± 0.3^a	7.8 ± 0.6^a
EC (dS/m)	3.2 ± 0.4^a	4.1 ± 0.5^b
N (g kg^{-1})	12 ± 2^a	21 ± 3^b
C (g kg^{-1})	320.5 ± 32^a	350.6 ± 24^a
C/N	27.08	16.1
P (%)	0.37 ± 0.01^a	0.41 ± 0.02^b
K (%)	0.42 ± 0.03^a	0.57 ± 0.01^b

Results are expressed on dry weight basis

Data are the means of four replicates. Values followed by different letters are significantly different according to the Dunnett's test at $P = 0.05$

EC electric conductivity (mS/m), *C* carbon, *N* nitrogen, *C/N* ratio carbon/nitrogen, *P* phosphorus, *K* potassium

Growth rate and water content

Growth rate of alfalfa plants was determined on stem length and leaves number at two times (measurement) at the end of winter (time 1) and after 35 days in spring (time 2). The growth rate was calculated by the following formula:

$$\text{Growth rate} = (\text{Measurement2} - (\text{Measurement1})/\text{number of days}.$$

The relative water contents (RWC) in the shoot system of alfalfa plants was determined using the following formula:

$$\text{RWC}(\%) = [(\text{Freshmatter} - \text{drymatter})/(\text{Turgid mass} - \text{Drymass})] \times 100.$$

After water imbibing, the samples were taken out of water and are well dried and instantly weighed to obtain the full turgid weight.

Mineral uptakes in alfalfa leaves

Alfalfa leaves from treatment groups were sampled at the first harvest of the spring period for both years by abscising from plants to determine nitrogen, phosphorus and potassium contents. Total nitrogen was determined by the Kjeldahl method with two steps (mineralization and distillation) (Pomeranz and clifton 1987). Potassium ion was determined after nitric acid (at 0.5%) digestion of the dry matter leaves sample, by a flame photometer (Eppendorf Elex 6361). Phosphorus was determined by the vanadomolybdophosphoric acid (or yellow) method described by Jackson (1985).

Statistical analysis

Results were subjected to univariate and multivariate statistical analyses: one-way analysis of variance (ANOVA) and Dunnett's test were performed as a post hoc analysis for means comparison. All the tests were achieved with a significance level ($P < 0.05$) and all statistical analyses were performed using SPSS statistical software version 16.0.

Results and discussion

Soil properties

Results of soil analysis after 2 years of applying compost/manure are shown in Table 2. The main chemical properties were differently affected by amendment treatment. However, the amended or unamended soils had similar texture (loamy sandy). Overall, the P-compost application at 30 t ha^{-1} improved significantly both organic matter (OM) and water retention (WR) capacity. Contrary, the plots amended with cow manure show the lower OM percentage (0.25%) than the control (0.82%) and P-compost (0.81%) ones. However, the soil amended with P-compost presents approximately the double of water retention capacity (60%) than plots amended with cow manure or control (37.6 and 33%, respectively). Likewise, N'Dayegamiye et al. (2005) showed that the incorporation of municipal solid waste compost (20–60 t ha^{-1}) improved the organic matter content of a sandy loamy soil. Furthermore, Celik et al. (2004) reported that the soil organic matter at depth of 0–15 cm in a clay-loam soil was higher in plots fertilized with manure and compost during 5 years than in plots treated with mineral fertilizer. Nogales et al. (1996) has reported that the application of compost and worm compost made from household waste has increased the water-holding capacity of soils. Also, Weber et al. (2007) showed that the soil organic carbon content increased significantly after 1 year of the application of two kinds of commercial composts at 60 t ha^{-1} in a loamy sandy soil. Ben Achiba et al. (2010) reported that the addition of the two organic amendments, municipal solid waste compost compared to farmyard manure, significantly increased the organic carbon of Tunisian calcareous soil. In addition, increasing the soil organic matter content improves the soil physical properties, such as structure and porosity, water retention and movement, and favors the establishment of carbon cycling (Gil et al. 2008). Recently, Montemurro et al. (2015) reported that different organic amendments from agro-industrial wastes improved soils and organic lettuce crops.

Electrical conductivity reflects the total amount of dissolved ions available in the water or the salinity of the soil (Lim et al. 2015a). Our results showed that the control soil (unamended) had the highest mean values of electrical conductivity (EC = 9.6 mS cm^{-1}). However, soil fertilized two seasons with cow manure or P-compost at 30 t ha^{-1} showed a decreasing on EC to 3.76 and 2.25 mS cm^{-1}, respectively (Table 2). It has been confirmed that the application of organic matter to soils affected by salinity can increase sodium chloride (NaCl) leaching, reduce the exchangeable sodium rate and electrical conductivity, and increase water infiltration, water-holding capacity, and aggregate stability (El-Shakweer et al. 1998).

Yield parameters

Alfalfa plants receiving cow manure or date palm compost produced more aerial fresh biomass compared to that of the control treatment (Fig. 1 A), in the two crop years. Plants amended with 30 t ha^{-1} P-compost and cow manure produced 21% and 19% higher fresh biomass, respectively, in the first season, compared to the no compost-treated plants (conventional fertilization). In the second season, the application of P-compost or cow manure improved biomass fresh, respectively, by 28 and 25%, compared to the control treatment. As regard the dry matter, in the two growing seasons, there were no significant effects of soil amendment treatment (Fig. 1b). However, with reference to the grain yield in the both 2 years, the P-compost slightly enhanced this trait than control and manure treatments. But this effect is not statistically significant (Fig. 1d). It was also found that the relative water content in shoot system was statistically similar among treatments with RWC levels around 80% (Fig. 1c). In the same way, Ouni et al. (2014) reported that the amendment of soil with municipal solid waste compost (MSC) at 100 t ha^{-1} increased plant

Table 2 Soil characteristics after 2 years of applying cow manure and P-compost

Amendments	P-compost	Cow manure	Control	*P* value
OM (%)	0.82 ± 0.13^{a}	0.25 ± 0.07^{b}	0.81 ± 0.09^{a}	*
$CaCO_3$ (%)	4.75 ± 1.1^{a}	5.25 ± 1.2^{a}	6.00 ± 0.5^{a}	Ns
Gyp (%)	28.75 ± 3.2^{a}	24.5 ± 2.9^{a}	25.5 ± 3.3^{a}	Ns
EC (mS/m)	2.25 ± 0.9^{c}	3.76 ± 1.2^{b}	9.66 ± 1.8^{a}	**
WR (%)	60 ± 5.7^{a}	37.6 ± 2.6^{b}	33.1 ± 2.3^{b}	*
pH	7.6 ± 0.1^{a}	7.7 ± 0.2^{a}	7.5 ± 0.2^{a}	Ns
Texture	Loamy sandy	Loamy sandy	Loamy sandy	–

Data are the means of four replicates. Values followed by different letters are significantly different according to the Dunnett's test at $P = 0.05$

* Significant

** Highly significant

Ns non significant, *OM* organic matter (%), *Gyp* gypsum (%), *EC* electric conductivity (mS/m), *WR* water retention (%)

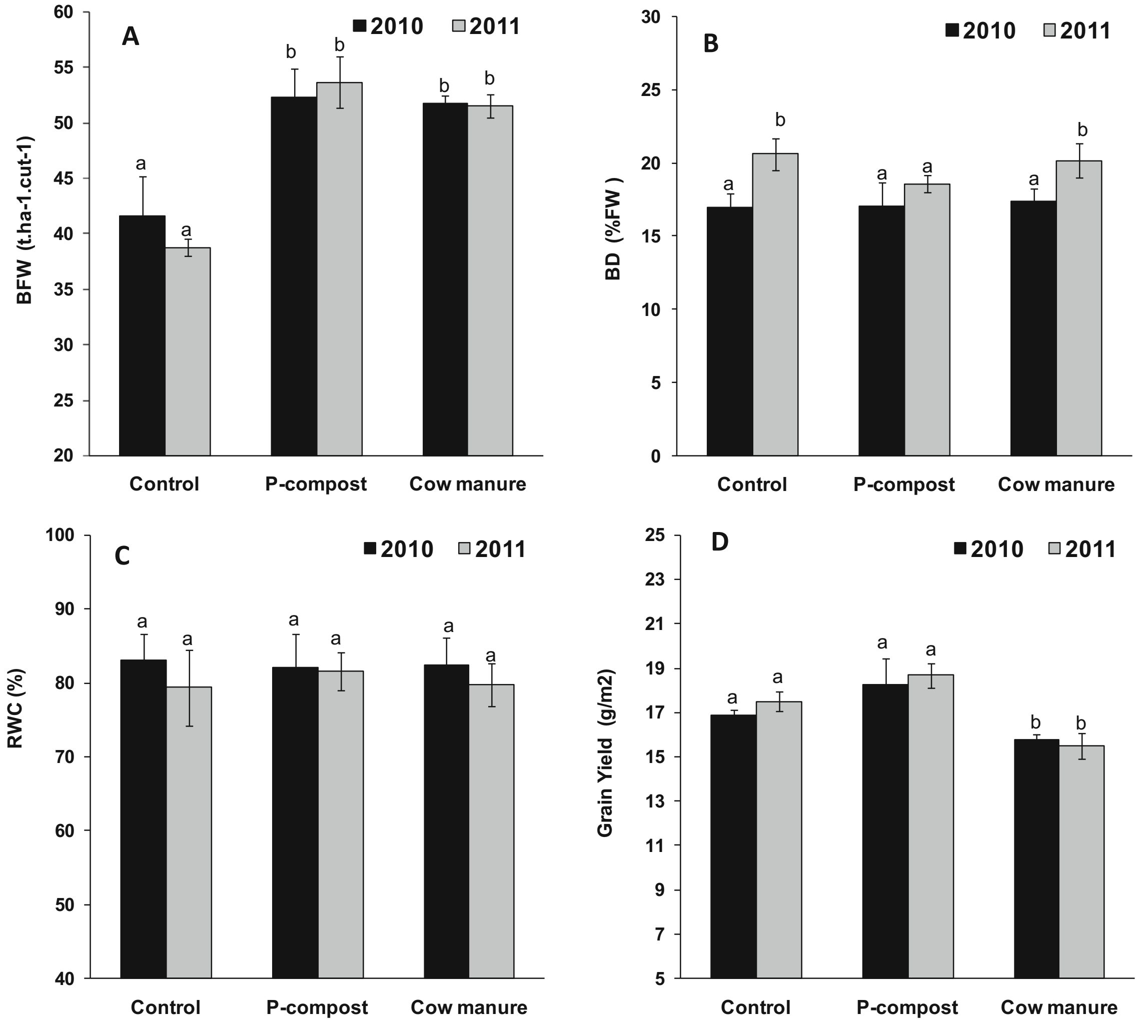

Fig. 1 The effect of date palm compost and cow manure application on fresh matter of aerial parts per harvest—BFW (**a**), dry matter percent (**b**), relative water content (**c**) and grain yield (**c**) in two crop seasons of alfalfa. Values with different letters are statistically according to a Dunnett's test at $P = 0.05$

yields of two forages species (*H. vulgare* and *P. monspeliensis*). The same author confirmed that the existence of compost increased shoot and root dry mass by 33 and 41%, respectively, in *H. vulgare*. Verlinden and McDonald (2007) reported that compost amendment improved *Celosia argentea* and *Limonium sinuatum* yield. Accordingly, in the current study, the comparison of control and P-compost treatments showed that P-compost application increase biomass weights of alfalfa with maintain high RWC. As a result, the increased production could be due to the improvement of physiological parameters such as photosynthesis, water balance, stomata conductance, and nutrient nutrition.

Stem and leaves growth rate

The growth rate of alfalfa stems and leaves was determined from the end of winter (just after winter dormancy) up to 35 days in spring to estimate the perennial capacity of alfalfa after applying P-compost or cow manure (Table 3). Overall, no significant differences were observed between amended and unamended plots in the first season (2010) for both rates (stem length rate and leaf number rate). Contrarily in the second season (2011), the stem length rate significantly increased in both P-compost (+ 18.5%) and cow manure (+ 16.7%) plots compared to the control treatment. Also, the number of leaves rate was increased under P-compost fertilization (0.67 leaf/day) compared to both control (0.56 leaf/day) and cow manure (0.54 leaf/day) treatments. Similarly, previous studies reported that

Table 3 Effect of P-compost and cow manure on growth rate of alfalfa

Year	Treatments	SL1	SL2	SLR	LN1	LN2	LNR
2010	Control	9.20 ± 2.73[a]	47.58 ± 6.22[a]	1.10 ± 0.14[a]	4.50 ± 2.06[a]	20.90 ± 5.67[a]	0.47 ± 0.13[a]
	P-compost	9.73 ± 2.34[a]	46.55 ± 5.20[a]	1.05 ± 0.13[ab]	3.55 ± 0.86[ab]	19.85 ± 5.47[a]	0.47 ± 0.15[a]
	Manure	8.31 ± 2.60[ab]	44.90 ± 8.23[ab]	1.05 ± 0.19[ab]	3.67 ± 1.04[ab]	17.67 ± 7.60[ab]	0.40 ± 0.22[ab]
P value		Ns	Ns	Ns	Ns	Ns	*
2011	Control	12.95 ± 3.00[a]	54.25 ± 11.3[a]	1.18 ± 0.27[a]	7.90 ± 2.41[a]	26.90 ± 2.2[a]	0.54 ± 0.26[a]
	P-compost	12.30 ± 2.90[a]	62.95 ± 11.2[a]	1.45 ± 0.29[b]	6.65 ± 2.06[ab]	30.05 ± 3.12[b]	0.67 ± 0.23[b]
	Manure	12.63 ± 2.07[a]	61.90 ± 8.40[a]	1.41 ± 0.24[c]	6.95 ± 2.06[ab]	26.65 ± 2.30[a]	0.56 ± 0.20[a]
P value		Ns	Ns	*	Ns	**	**

Data are the means of four replicates. Values followed by different letters are significantly different according to the Dunnett's test ($P \leq 0.05$)

Ns non significant, *SL1* stem length at beginning of spring (cm), *SL2* stem length after 35 days (cm), *SLR* stem length rate, *LN1* leaf number at the beginning of spring, *LN2* leaf number after 35 days, *LNR* leaf number rate

* Significant; ** highly significant

compost application increased the growth of ryegrass and tall fescue (*Festuca arundinacea*) (Park et al. 2011). Singh and Agrawal (2008) studied the positive effects in some plants (sunflower, maize, barely, etc.) regarding the growth, fresh and dry weights, and photosynthesis rate of some plants. Thus, municipal compost application can be used to improve the growth and development of plant crops (Zaka et al. 2003; Sharma and Minhas 2005). From our study, we could deduce that incorporation of P-compost at 30 t ha^{-1} could stimulate alfalfa growth by a positive effect on plant length and leaf expansion. Besides, according to Balakrishnan et al. (2010), compost at moderate doses can activate plant growth via its positive effect on leaf expansion.

Nitrogen, a phosphorus and potassium content in alfalfa leaves

Palm date compost application influenced significantly the minerals uptake in alfalfa (Fig. 2), especially for phosphorus and potassium. Compared to the control treatments, P-compost improved the accumulation of the three essential minerals in alfalfa leaves (N, P and K), except K in 2011 which was slightly decreased. At the first crop season (2010), the P-compost application had a significant positive effect on the three minerals contents compared to the control, with increasing rates of + 32% for P, + 25% for K and + 6% for N. Also these contents were even significantly higher than under cow manure amendment (Fig. 2). However, at the second season (2011), the P-compost has improved only P and N uptake in alfalfa leaves.

Alfalfa is a legume known by the high nitrogen content due to their symbiosis with *Rhizobia* bacteria. So the increase of N accumulation in leafs after compost applying could be explained by the positive impact of P-compost on biological nitrogen fixation and/or N absorption. Furthermore, mineralization of organic matter in used organic amendments leads to an interesting release of nutrients for plants, in particular nitrogen. In amended soils, the kinetics of mineralization depends on soil texture, moisture regime and the kind of added organic matter (Du Laing et al. 2008). Hargreaves et al. (2008) reported that compost organic nitrogen mineralization dependents on several factors including *C*/*N* ratio of raw material, composting conditions, compost maturity, time of amendment, and compost quality.

In fact, compost supplying in such soil enriches the rhizosphere with micro- and macro-nutrient elements and counteracts nutrient depletion (Lakhdar et al. 2008). For some forage species, Ouni et al. (2014) reported that the mineral content of both shoots and roots were higher in plants grown in soils amended with MSW compost. Therefore, the increasing on alfalfa growth under amended soils by date palm compost (30 t ha^{-1}), obtained in our study, may be due to the enhance of mineral nutrition. Similarly, plants growth is often positively associated with nutrient amounts as showed in several studies. Phosphorus is one of the most essential plant nutrients and its accumulation in alfalfa is significantly improved by supplying P-compost at 30 t ha^{-1}. There is considerable evidence in the literature dealing with the increase of phosphorus solubility following organic material application (Sanyal and De Datta 1991). Concerning the potassium accumulation, results showed inversely behavior among the first and second crop seasons under the different amendment treatments (Fig. 2c). Bhattacharyya et al. (2007) found high residual potassium quantity in compost amended soil surrounded by clay minerals and organic matter and not immediately replaceable.

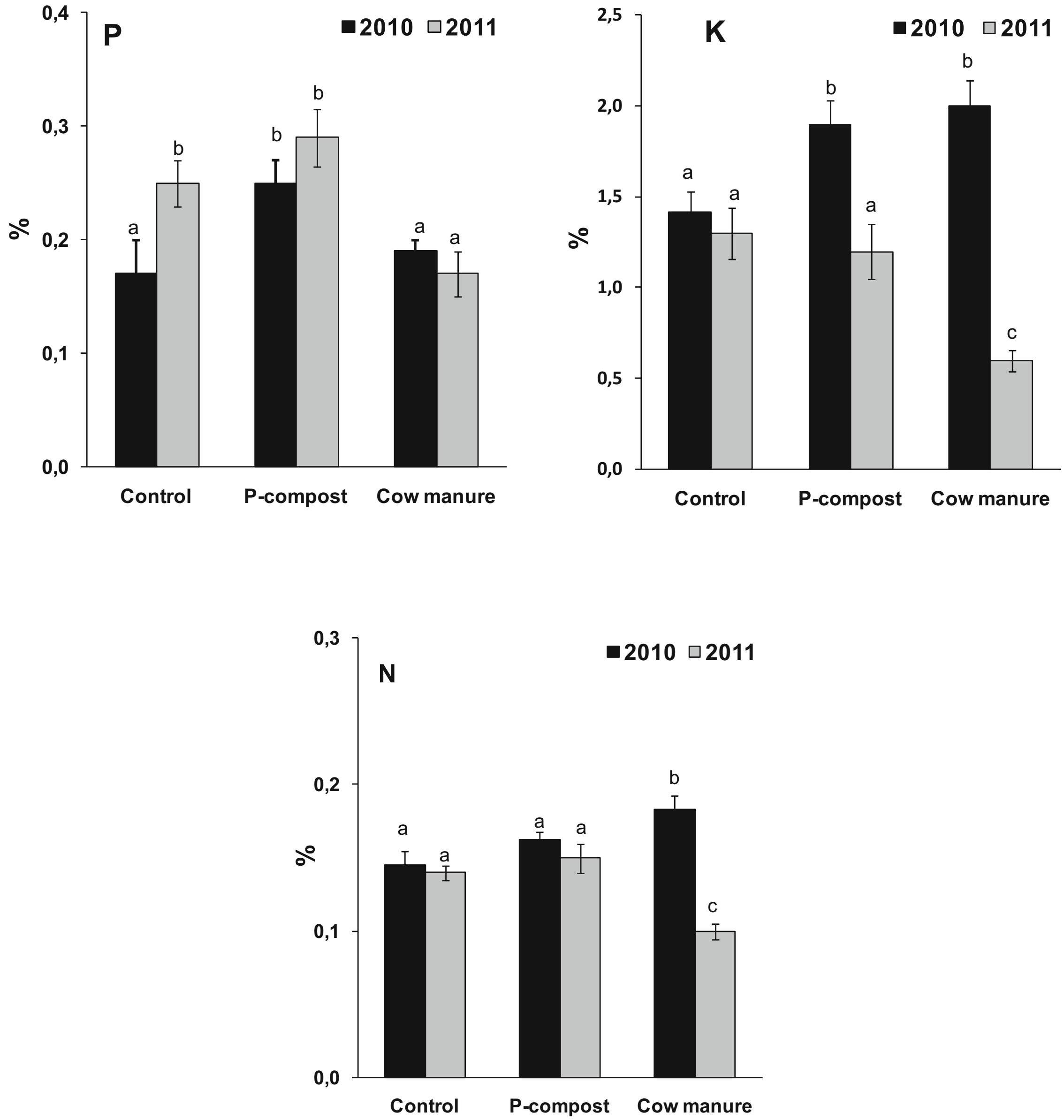

Fig. 2 Phosphorus (P), potassium (K) and nitrogen (N) uptake in alfalfa according to the different fertilization treatments. Values with different letters are statistically according to a Dunnett's test at $P = 0.05$

Conclusions

The present study reveals that application of date palm compost (at 30 t ha^{-1}) is quite beneficial in field-grown *Medicago sativa* plants. It produced higher yields than control and a significant higher rate of growth. The essential mineral uptake (N, P and K contents) in alfalfa leafs was improved by the date palm compost as well. This behavior could be attributed to the positive effects of the compost on soil properties. The application of palm waste compost at 30 t ha^{-1} increased significantly the principal soil properties (organic matter and water retention capacity) and decreased their electric conductivity. To conclude, the P-compost at appropriate dose could be used as a good organic fertilizer for other crops surrounded date palm trees and could replace chemical fertilization with satisfactory results.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest.

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