Effect of mulch on soil properties under organic farming conditions in center of Saudi Arabia

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Abstract: The mulch application on top of soil surface may effect on soil physical conditions by reducing evaporation losses, soil moisture and soil temperature which in turn affect the distribution of soil elements through soil profile. This work presents a study of the effects of mulch on movement and distribution of soil properties including pH, soil salinity and major nutrition plant available N, P and K in organic palm farming by use different irrigation rates. The decreasing in soil pH more pronounced in surface layer compared to subsurface layers. Soil salinity of surface layers were lower than sub surface layers in mulched treatments for both tow time samples, under organic farming system, Soil moisture and mulch were shown to have a strong indirect influence on the amount of available soil nitrogen, phosphorus and potassium. The highest value of total nitrogen in the soil was recorded in the presence of mulch with the availability of 100 % of the recommended irrigation, where the conditions are very suitable for the mineralization N process. With respect of available phosphorus and potassium, it has given highest values in the presence of mulch with the availability of moisture up to 70% and 85% of recommended irrigation, respectively.

[Abdulaziz Alharbi. **Effect of mulch on soil properties under organic farming conditions in center of Saudi Arabia.** *J Am Sci* 2015;11(1):108-115]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 14

Key Words: organic farming, palm, mulching, movement major nutrition nutrient

1. Introduction

Using mulch on top of the soil surface may improve soil moisture conditions. Mulch benefits crop yield by improving soil physical conditions, including improved structural stability in the topsoil **(De Silva and Cook, 2003**). A variety of types of mulch leads to an increase in soil moisture content as a result of decreased evaporation from the soil surface compared to that of un-mulched soil (Maged, 2006). Generally, mineral mulch is impervious to water vapour and is thus expected to conserve soil water more efficiently than organic mulch (Lei *et al.*, 2004). Also, the combination of mulching with tillage increased conservation of soil moisture (Grevers *et al.*, 1986; Bhagat and Acharya, 1987). The higher moisture content was always in the 0-60 cm soil layer of the mulched compared to bare soil (Ramakrishna *et al.*, 2006). Diaz *et al.* (2005) reported the greatest reduction in soil moisture content in the case of mulched soil at 10 cm (92%), followed by soil moisture content at 5 cm (83%), and at 2 cm (52%).Some studies instigated the effect of gravel mulch on evaporation by comparing cumulative evaporation rate from soils mulched by gravel with a bare soil surface in the laboratory (Mellouli *et al.*, 2000; van Wesemael *et al.*, 1996; Groenevelt *et al.*, 1989; Modaihsh *et al.*, 1985). The covering of surface soil by gravels and coarse sand can reduce evaporation by 10-20% of that occurring from a wetted un-mulched soil surface (Fang *et al.*, 1993; Unger, 1971; Lemon, 1956). The gravel mulch decreases the area of soil surface available for evaporation (Nachtergaele *et al.*, 1998). Effect of mulching on conserving moisture and increasing productivity had been reported for many crops (Zhang et al., 2005, Verma and Acharya, 2004a,b; Li et al., 2005; Huang et al., 2005; Rahman et al., 2005; Araki and Ito, 2004; Incalcaterra et al., 2003; Tariq et al., 2001; Kumar et al., 2003; Haq, 2000; Kar and Singh, 2004). Whileweed growth controlling by potential of mulch has been studied by Erenstein (2002). Using irrigation system combined mulch is advocated for better uptake of water by wheat (Li et al., 2004). During the first stage of evaporation, the mulch on top of the soil decreases capillary diffusion, and water moves from the soil surface to the mulch surface mostly in the vapour phase (Li, 2003). Furthermore, the mulch reduces evaporation of soil water by shading the soil surface from the sun; shading is most effective during the first stage of evaporation when the soil surface is wet (Tolk et al., 1999). On the other hand, Effect of mulching on soil temperature depends on the type of the mulch. Heat storage in the mulch layer is small, but the available energy at a mulch site will be affected by the heat storage in the mulch layer, see e.g. Price et al. (1998). Several researchers have found that the mulch influenced on soil temperature (Epistein, 1966; Hay and Allen, 1978; Bristow, 1988; Kar, 2003; Kar and Singh, 2004). The impact of mulching on bulk density depends on soil properties, climate and type of mulch. While some study explained the mulch reduced soil bulk density (Unger and Jones, 1998), and some of them not found any effect of mulch on soil bulk density

(Acosta et al., 1999; Duiker and Lal, 1999). Whilst (Bottenberg et al., 1999) reported that the mulch increased bulk density of soil. On the other hand, addition the organic mulch above soil surface influence soil properties and may affect the movement of some plant nutrient, for example mulching at rate low then 2.25 Mg/ha from crop residue reduced losses of NO_3-N, P, K, Ca and Mg, additional to increased soil organic matter (Rees et al., 2002), beside that there are relationship between crops residue amount andsoil organic matterprincipally in soil surface (Reicosky et al., 1995). (Kar and Kumar, 2007) reported that the mulch increased available phosphorus, potassium and organic carbon might have enhanced crop growth and yield production especially in the mulched treatments. Therefore, the objective of this research is to study the effects of mulch on soil properties including pH, soil salinity, available N, P, and K through different soil depths in organic palm farming by use different irrigation rates.

2. Materials and methods

2.1 Study area

A field experiment was conducted at Oukaf Al Rajhi Al khairiah between April and October 2014. The study area is located in Albaten (26°17′ 47″ N, 44°09′30″ W), Buraydah, Saudi Arabia at an altitude of approximately 26m. The texture of the soil was sandy loam (sand 79.17%, silt 8.33% and clay 12.5%) with date palm crop. The soil (0–30 cm) has bulk density 1.58 g/cm^3. Mean monthly air temperature, relative humidity, wend speed, sunshine hours, net radiation and total rainfall during the period of experiment are presented in Table 1. Fifty kg Organic fertilizer (residues cow) was applied for every palm mixed with 0-30 cm soil surface in January 2013. Chemical analysis of organic fertilizer was showed in Table 2. Three irrigation treatments were applied start from first of March 2014 at 100%, 85% and 70% from the recommended water requirements for palm. Water salinity was 2.31 dS/m. Two layers mulch treatments were applied above soil surface, first layer from gravel rock 10 cm (1.14 g/ cm^2) and second layer 5cm palm leafs (0.17 g/ cm^2) starting from soil surface.

2.2 Soil analysis

Soil samples (0–30, 30-60 and 60-90 cm) were collected in early of season (April 2014) and end of season (October 2014) for analysis. Each sample was dried at laboratory room temperature (25 °C) to a constant weight and sieved (2 mm) to eliminate coarse soil particles. Electrical conductivity, EC (dSm^{-1}), and pH of soil samples were determined in saturated soil-pastes extract, by EC and pH meter, respectively. Total N was determined using the macro-Kjeldahl distillation method, available potassium was determined using a flame photometer and available phosphorus was extracted using 0.5 M $NaHCO_3$ solution and measured calorimetrically using ammonium moly date procedure by spectrophotometer according to Chapman and Pratt (1961) and Jackson (1973).

Table: 1 Mean weather conditions during experiment period

Months	Air temperature (C°)	Relative humidity (%)	Wend speed (Km/h)	Sunshine hours (h/day)	Net radiation (W/m^2)	Rainfall (mm)
April	25.9	52.9	44	5.7	390	13.2
May	29.8	45.8	42.9	6.5	438	11.2
June	33	16.5	30.7	6.8	535.6	0
July	33.5	18	29.6	7.3	520.7	0
August	33.6	21.9	32.2	7.3	474.6	0
September	32.1	26.9	27.4	10.3	422.8	1
October	27.8	41.2	32.6	10	349.3	5.3

Table: 2 Chemical analysis of organic fertilizer (residues cow)

EC dS/m	pH	Moist. %	C%	OM%	TN%	C/N Ratio
6.43	7.95	9.33	19.88	34.27	1.28	15.53

3. Results and discussion

Under organic farming conditions compost is considered the main source of nutrients, especially in dry areas. Therefore, the available nutrient concentration in the soil affected by any process, which will influence the decomposition process of organic fertilizers. In fact, it is noticed that the soil mulching maintains on the soil moisture and temperature, both of which affect the microorganism activity and microbial degradation of organic matter in the soil, as well as nutrient release from organic matter. Consequently, soil mulching has an indirect effect on soil chemistry and fertility. The data in table (3) showed response of soil pH for irrigation levels and mulch at different soil depths. There slightly decrease in soil pH for mulched treatments compared to unmulched treatment in all soil depths either in the beginning or end season. The data were non-significant in the beginning season. However, The decreasing in soil pH more pronounced in surface layer compared to subsurface layers. In the beginning season, the changes in soil pH between(With out-M+100%I) and (M+85%I) treatments were0.15, 0.09 and 0.06 for depths 0-30, 30-60 and 60-90 cm, respectively. Also, in the end season, soil pH values in treatment (With out-M+100%I) increased by 0.65, 0.28 and 0.19 for depths 0-30, 30-60 and 60-90 cm, respectively. Many studies have shown that soil pH decreases when organic mulches are used and that this decrease is proportional to the depth of these mulches (Tukey and Schoff, 1963; Billeaud and Zajicek, 1989 and Duryea et al., 1999).

Also, data showed that application of compost in arid land cause decrease in soil pH. Mulvaney et al. (1997) and Xia Zhu et al. (2013) observed that lower soil pH was in 50% WHC (water hold in capacity) compared with in 100% WHC treatment, which suggests that nitrification is stronger in drier conditions, as nitrification contributes to increases soil acidity (reduces pH). Also, other researchers reported that organic mulches cause reduce pH of the underlying soil (Billeaud and Zajicek 1989; Himelick and Watson 1990; Hild and Morgan 1993). Mulch induced pH reduction results from the addition or retention of organic matter, with organic acids produced from decomposition of plant-derived materials accumulating or leaching into the soil (Himelick and Watson 1990). On the other hand, soil pH value in surface layer were lower than sub surface layer with all irrigation levels. While, highest pH values recorded at deep layer. In fact, under organic farming, soil reaction (soil pH) is the result of two processes, ammonification and nitrification. With high soil moisture content, soil air percentage will decrease, so ammonification process will be dominant and soil pH will increase. In contrast, with low soil moisture content, soil air percentage will increase, so nitrification process will be dominant and soil pH will decrease. Reichman et al. (1966) reported that ammonification and nitrification of soil N were almost directly proportional to soil water content. Also, Yu-lin et al. (2013) added that net ammonification rate of soil N reached the maximum at the moisture of 15.2%. Net nitrification rates and net mineralization rates of soil N, however, reached their maximums at the moisture of 11.8% and decreased at the moisture of 15.2%. As expected that the aeration in deep layer (60-90 cm) less than those in surface layer. Consequently, soil pH in surface layer was less than that in deep layer.

Fig. (3): Response of soil pH for irrigation levels and mulch treatments at different soil depths.

Soil Depth, cm	End season				Beginning season			
	Treatments				Treatments			
	With out-M+100% I (C)	M+100% I	M+85% I	M+70% I	With out-M+100% I (C)	M+100% I	M+85% I	M+70% I
0-30	8.15	7.50	7.34	7.57	7.96	7.81	7.86	7.92
30-60	8.11	7.83	7.47	7.94	8.05	7.96	7.94	7.91
60-90	8.30	8.11	8.38	7.61	8.11	8.05	7.97	7.96
P	0.003	0.002	0.001	0.002	0.367	0.174	0.958	0.710

M=mulching; C=control; I=Recommended irrigation

Soil salinity was significantly affected by presence of mulch ($p \leq 0.05$).Soil salinity of surface layers were lower than sub surface layers in mulched treatments for both two time samples. The results in table (4) showed that treatment of (M+100%I) in the end season had indicated maximum reduction in soil EC, 2.36 dS/m compared to unmulched treatment (With out-M+100%I). The interpretation for this result was accordingly to Pakdel et al. (2013) who suggested that mulch can reduce soil EC in two ways, A: mulches reduced water evaporation of soil and so lead to reducing salt accumulation in soil; and B: water-soluble salts may be absorbed by mulch layer and lead to reducing of water EC when it reaches to the soil layer. Moreover, Hild and Morgan (1993) reported that the greatest effect of mulches on soil EC was observed in the surface of soil layer (0 to 5 cm) below the mulches. They also found that using mulch reduces water evaporation and maintains soil moisture. Therefore lead to reducing the accumulation of soluble salts in the soil surface and so electrical conductivity of soil can be reduced. Also, data showed that soil salinity values in different soil depth were affected by different irrigation levels. Soil salinity of treatment (M+100%I) recorded less value, 2.26 and 2.46dS/m in the beginning and end season respectively, compared other treatments.

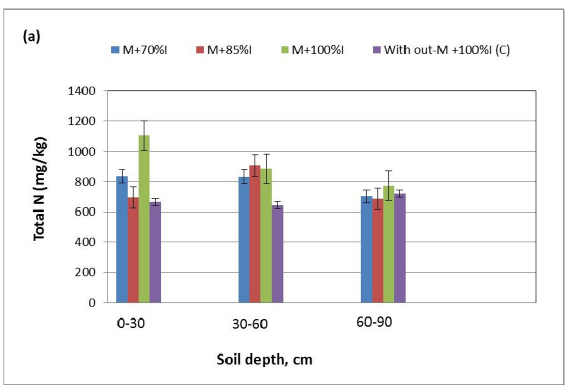
It could be attributed to the increase effect of irrigation water volume for treatment (M+100%I) on the top soil surface depth (0-30 cm) compared to other treatments, (M+ 85% I) and (M+70% I). Where, by increasing the water volume applied in each irrigation treatment, the soil salinity may be reduced as a result of the increased volume of water percolated the surface layer and then accumulated in deep layers. In similar study, Wang et al. (2011) reported that, at the end, salt leaching occurred during the growing season for each treatment as a result of the frequent irrigation, which resulted in the ECe value increasing with depth. However, the difference in soil salinity value between treatment of (M+100%I) and (M+ 85I) was 0.12 dS/m, 5.3% compared to treatment of M+100%I. This decrease in soil salinity level indicated that the soil salinity was improved and this may be due to that the amount of water irrigation in treatment (M+ 85% I) was suitable.

Table (4): Response of soil EC (dS/m) for irrigation levels and mulch at different soil depths.

Soil Depth, cm	End season				Beginning season			
	Treatments				Treatments			
	With out -M+100% I (C)	M+100%I	M+85%I	M+70%I	With out -M+100% I (C)	M+100%I	M+85% I	M+70% I
0-30	4.62	2.26	2.38	2.92	3.3	2.46	2.78	3.35
30-60	3.46	2.45	2.86	5.43	2.69	4.09	2.95	3.00
60-90	4.72	6.70	4.32	8.46	4.17	4.08	3.26	3.01
P	0.001	0.001	0.001	0.001	0.001	0.001	0.013	0.002

M=mulching; C=control; I=Recommended irrigation

Results, also, showed that soil N significantly affected by mulching process ($p \leq 0.05$) **(Fig.1)**. Total N in surface layer in mulched treatment (M+100%I) was higher than unmulched treatment (With out-M+100%I) by 31.0 and 65.9 % in thebeginningandend season, respectively. These results were confirmed by Tisdale et al. (1985) and Watt et al. (2010) who reported that mineralization capacity of nitrogen was higher at the soil surface while that mineralization and availability of nitrogen decreased with deeper layer.



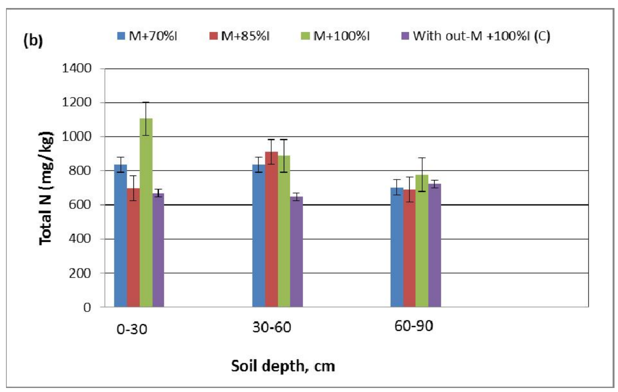


Figure (1): Response of total N (mg/kg) in soil for irrigation levels and mulch at different soil depths in (a) the beginning season, (b) the end season. M=mulching, C=control, I=Recommended irrigation

The addition of compost to the soil either increases the NH^{+}_{4}levelfrom ammonification or leads to a shift in soil pH, which promotes the growth of the nitrifying bacteria population. This may explain the higher nitrate concentration in mulched plots (Engel, 1934 and Pakdel et al. 2013). In addition, Myers (1975) demonstrated that nitrification had a distinct temperature optimum between 25 and 35°C, whereas ammonification reached its maximum at 50 to 70°C. Hence, unfavorable microclimatic conditions in the topsoilof no-mulched plots reduce the number and/or the efficiency of the nitrifying soil microorganisms.

The data in (Fig.2) indicated that available potassium concentrated in surface layers. While, the medial layers had lowest concentration of potassium. Results showed that soil K significantly affected by mulching process ($p \leq 0.05$). Available potassium in surface layer for mulched treatment (M+100%I) was higher than unmulched treatment (With out-M+100%I) by 27.6 and 20 %compared to unmulched treatment in the beginning and end season, respectively. With respect of availability phosphorus, at soil surface layer for mulched treatment (M+100%I), it was higher than unmulched treatment (With out-M+100%I) by 76.1 and 59.3 % compared to unmulched treatment in the beginning and end season**,** respectively (Fig.3). Similar results were obtained by Green lee and Rakow (1995) who mentioned that potassium and phosphorus availability under mulch treatment increased in comparison with no-mulched treatment. Tukey and Schoff, (1963) observed increasing amounts of available soil P and K under mulches. They suggested that the release of nutrients from decomposing mulches (rapidly and slowly decomposing) might have a positive effect on the soil.

Presence of mulchcaused adjusting soil temperature and maintaining soil moisture that helped better phosphorus available condition in soil. Plots mulched with organic materials had significantly higher soil K concentrations than nomulched plots (Broschat, 2007). Other possibility, the organic acids produced during the decomposition of soil organic matter complexes the metal cations Ca, Al and Fe, hereby helping in solubilization of native P and reduction in Psorption (Dahiya and Malik, 2002).

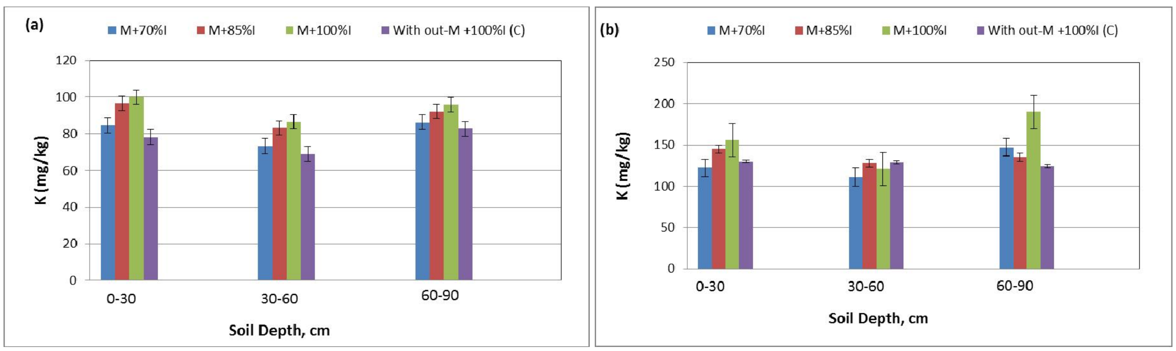


Figure (2): Response of available K (mg/kg) in soil for irrigation levels and mulch at different soil depths in (a) the beginning and (b) the end season. M=mulching, C=control, I=Recommended irrigation

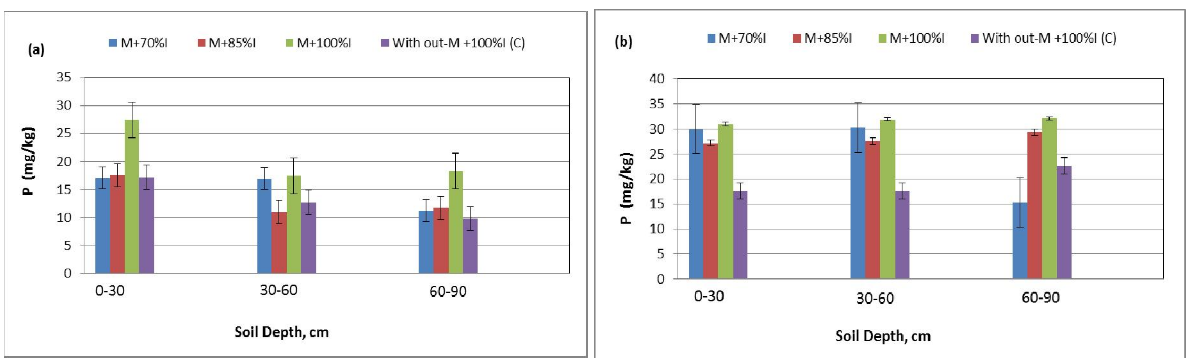


Figure (3): Response of available P (mg/kg) in soil for irrigation levels and mulch at different soil depths in (a) the beginning season,(b) the end season. M=mulching, C=control, I=Recommended irrigation

It may be worth to mention that the concentrations of nutrient in the end season were higher than those in the beginning ones. It may due to mineralization process for compost during the season. Cambardella et al. (2003) reported that the composting process affects the availability of nitrogen and other nutrients when the compost is applied to the field.

4. Conclusion

There slightly decrease in soil pH for mulched treatments compared to unmulched treatment in all soil depths either in the beginning season or end season. The data were non-significant in the beginning season. However, The decreasing in soil pH more pronounced in surface layer compared to subsurface layers.Soil salinity was significantly affected by presence of mulch ($p \leq 0.05$). Soil salinity of surface layers were lower than sub surface layers in mulched treatments for both two time samples, treatment of (M+100%I) in the end season had indicated maximum reduction in soil EC, 2.36 dS/m compared to unmulched treatment (With out-M+100%I). Total N in surface layer in mulched treatment (M+100%I) was higher than unmulched treatment (With out-M+100%I) by 31.0 and 65.9 % in the beginning and end season, respectively. Available potassium in surface layer for mulched treatment (M+100%I) was higher than unmulched treatment (With out-M+100%I) by 27.6 and 20 % compared to unmulched treatment in the beginning and end season, respectively. In soil surface layer for mulched treatment (M+100%I), available phosphorus was higher than unmulched treatment (With out-M+100%I) by76.1 and 59.3% compared to unmulched treatment in the beginning and end season**,** respectively.

Finally, under organic farming system, Soil moisture and mulch were shown to have a strong indirect influence on the amount of available soil nitrogen, phosphorus and potassium. The highest value of total nitrogen in the soil was recorded in the presence of mulch with the availability of 100 % of the recommended irrigation, where the conditions are very suitable for the mineralization N process. With respect of available phosphorus and potassium, it has given highest values in the presence of mulch with the availability of moisture up to 70% and 85% of recommended irrigation, respectively.

Acknowledgements

I would like to express my gratitude to Oukaf Al Rajhi Al khairiahfor their support.

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1/18/2015