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Research Article

Seasonal Variation in Soil Temperature, Physico-Chemical Properties and Micronutrient Availability in Soils of Pear (*Pyrus communis* L.) Orchard under Semi-Arid Environment

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ABSTRACT

The present study was conducted to evaluate the seasonal variation in soil temperature, physico-chemical and micronutrients availability in soils of Pear (*Pyrus communis* L.) under semi-arid environment. Soil temperature was higher than environmental temperature at all three depths in all seasons. The upper soils (0-5 cm) showed higher soil temperature, decrease with increase in depth. It was also observed that soil temperatures in all soil depth were higher during monsoon. The $CaCO_3$ content was low in 0-5 cm soil during all seasons as compared to 5-15 cm and 15-30 cm soil depths with no seasonal variations. Similarly, no variation in soil pH was observed due to change in season. The pH ranged from 8.07 to 8.17 with mean value of 8.12 in upper soil (0-5 cm) and increase with soil depth. Whereas, the EC varies from 0.34-0.40 dSm^{-1} in surface (0-5 cm) with mean value of 0.36 dSm^{-1} and decrease with increase in depth, having higher values in summer seasons. The surface soils (0-5 cm) showed higher content of Fe, Cu, Zn and Mn than 5-15 and 15-30 cm soil layers which exhibited a decreasing trend with increase in soil depth. The soil temperature influence the micronutrient availability and higher soil temperature increase the DTPA extractable Fe, Zn and Mn content of soil, while decreasing trend was reported in Cu availability. The micronutrients (Fe, Zn and Mn) were higher during the monsoon followed by summer, autumn and winter season.

Key words: Seasonal Variation, Soil Temperature, Soil pH, Micronutrient, Semi-arid environment

Introduction

Pear, the most commonly grown fruits in the world is grown in different parts of the world, due to its wider adoptability under different agro-climatic conditions. In India, pear occupies third place in temperate fruits in area and production and can be grown from foot hills to high hills experiencing 500 to 1500 chilling hours (Rathore, 1991). The sub-tropical pears are recommended for cultivation in Punjab, experiences 200 to 300 chill hours (Thind and Mahal, 2019) for warmer regions to break down growth inhibitors in flower and leaf buds. Nutrition plays an important role in maintain the quality and production of fruits. Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants. The horticultural crops suffer widely by zinc deficiency followed by manganese, copper, and iron (Kumar *et al.,* 2018). Micronutrients are key elements, play very important role in plant growth and development as well as various enzymatic activities and synthesis. Their acute deficiencies some time poses the problem of incurable nature (Kumar, 2002). These micro-nutrients also help in uptake of macro-nutrients and play an active role in the plant metabolism process starting from cell wall

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development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, nitrogen fixation and reduction (Das, 2003). The sufficient amount of micronutrients needed for better growth which results in higher yield due to increased growth, better flowering and higher fruit set in mandarin orange (Ram and Bose, 2000).

The soil is a natural body, separate into horizons of unconsolidated minerals and organic constituents, of variable depth which differs from the parent material in morphology, physical properties, chemical properties and biological characteristics (Rai, 2002). It is major sources for plant nutrients; however, their nutrient availability varies during the growing season depending on soil characteristics such as organic matter content, soil pH and cation-exchange capacity (Cancela *et al.*, 2002; Strahm and Harrison, 2007). Soil temperature is the function of heat flux in the soil as well as heat exchanges between the soil and atmosphere (Elias *et al.*, 2004). It varies seasonally and daily, which governs the soil physio-chemical and biological processes (Buchan, 2001), also the availability of soil nutrients and plant growth. Environmental factors affect soil temperature by either controlling the amount of heat supplied to the soil surface and the amount of heat dissipated from the soil surface down the profile. Little information is available on seasonal variation in soil temperature as well as physico-chemical and micronutrient availability in soils under semi-arid environment. Therefore, the present study was carried out to assess the seasonal variation in soil temperature, physico-chemical and micronutrient availability in soils of Pear (*Pyrus communis* L.) under semi-arid condition of Punjab.

Materials and Methods

Characteristics of the study site

The present study was carried out at Punjab Agricultural University, Regional Research Station, Bathinda, located at 30°12′39.58″ N latitude; 74°56′43.7″ E longitude; with an elevation of 202 m above mean sea level. The climate of the area is characterized by a large seasonal variation as well as fluctuations both in monthly rainfall and temperature. The district falls in the semi arid region of Punjab having annual average rainfall of 523 mm. As per meteorological observatory located at PAU, Regional Research Station, characteristics of different environmental parameters during the study period were presented in Fig. 1. Duing 2016-17 and 2017-18 value of T_{min} ranged from 3.5-27.7°C and 3.3-26.6°C with maximum value in monsoon season, however, the value of T_{max} ranged from 16.5-42.0°C and 15.7-43.3°C with maximum value in summer season, respectively (Fig. 1). A large variation (~20.0°C) in T_{max} was reported during the summer and monsoon season with mean of 35.5°C, whereas; in winter season the value of T_{min} drops up to 3.3°C. The morning relative humidity (Rhm) varied from 78.1- 97.3% in winter, 74.1-99.1% in autumn, 56.1-91.0% in monsoon and 39.3-86.9% in summer. Whereas, the evening relative humidity (Rhe) ranged from 36.0-73.0% in winter, 30.6-65.9% in autumn, 36.1-72.1% in monsoon and 16.7-54.3% in summer (Fig. 1). Higher variation in Rhm was observed in summer and monsoon season, however, more variation in Rhe was observed in autumn and winter season.

Soil sampling and analysis

The soil of the study area was sandy loam with sand, silt and clay content of 79.63, 12.11 and 8.26%, respectively and a bulk density of 1520 kg m^{-3}. Soil sampling was done randomly from ten (10) selected pear (*Pyrus communis* L.) trees at three depths: 0-5 cm, 5-15 cm and 15-30 cm with the help of auger. The soil samples were collected from 4 sides of the trunk under the plant canopy, mixed and prepared a composite sample of each depth, placed in labelled plastic bags. Collected samples were transferred to the laboratory for analysis in every month during 2016 to 2018. The soil temperature was recorded at 3 depths (5 cm, 15 cm and 30 cm) on daily from (2016-2018) using dial gauge soil thermometer (Accel Scientific Instrumetns, ACME-807) by inserting the sensor needle below the soil surface twice a day at 7:30 hrs and 14:30 hrs. The soil samples were dried and prepared for the analysis of micronutrients. The pH and EC

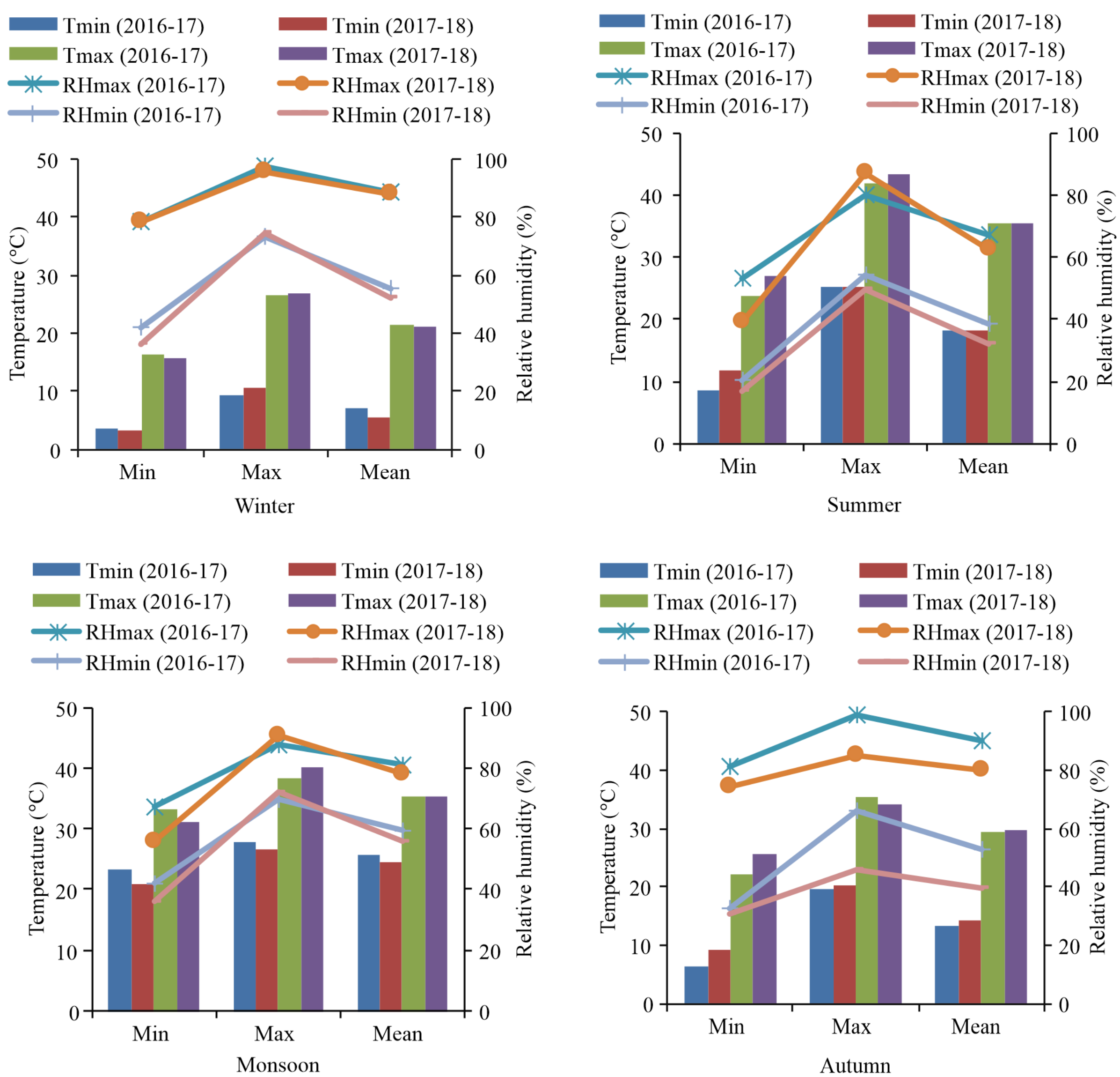

Fig.1. Seasonal environmental temperature and relative humidity during the study period

were determined in 1:2 soils: water suspension using pH meter and EC meter (Jackson, 1973). Available micronutrients (Fe, Zn, Cu and Mn) in soil were determined using the procedure of Lindsay and Norvell (1978). The extracting solution consisted of 0.005 M DTPA (diethylene triamine penta-acetic acid), 0.01 M $CaCl_2$ and 0.1 M TEA (Tri ethanol amine) buffer adjusted to pH 7.3. Ten grams of air-dried soil was shaken with 20 ml of extracting solution for 2 hours at 25ºC and filtered. Concentration of nutrients in the extract was determined by atomic absorption spectrophotometer with 248.3, 213.9, 324.7 and 279.8 nm wavelengths for Fe, Zn, Cu and Mn, respectively. The meteorological and soil data were arranged in four climatologically seasons as categorised by India Meteorological Department (IMD) *viz.* winter (December to February), summer (March to May), monsoon (June to September) and autumn (October to November). For further statistical analysis of data, Microsoft Excel (2007) software was used.

Results and Discussion

Soil temperature

The seasonal variations in mean soil temperature were presented in Fig. 2. The soil

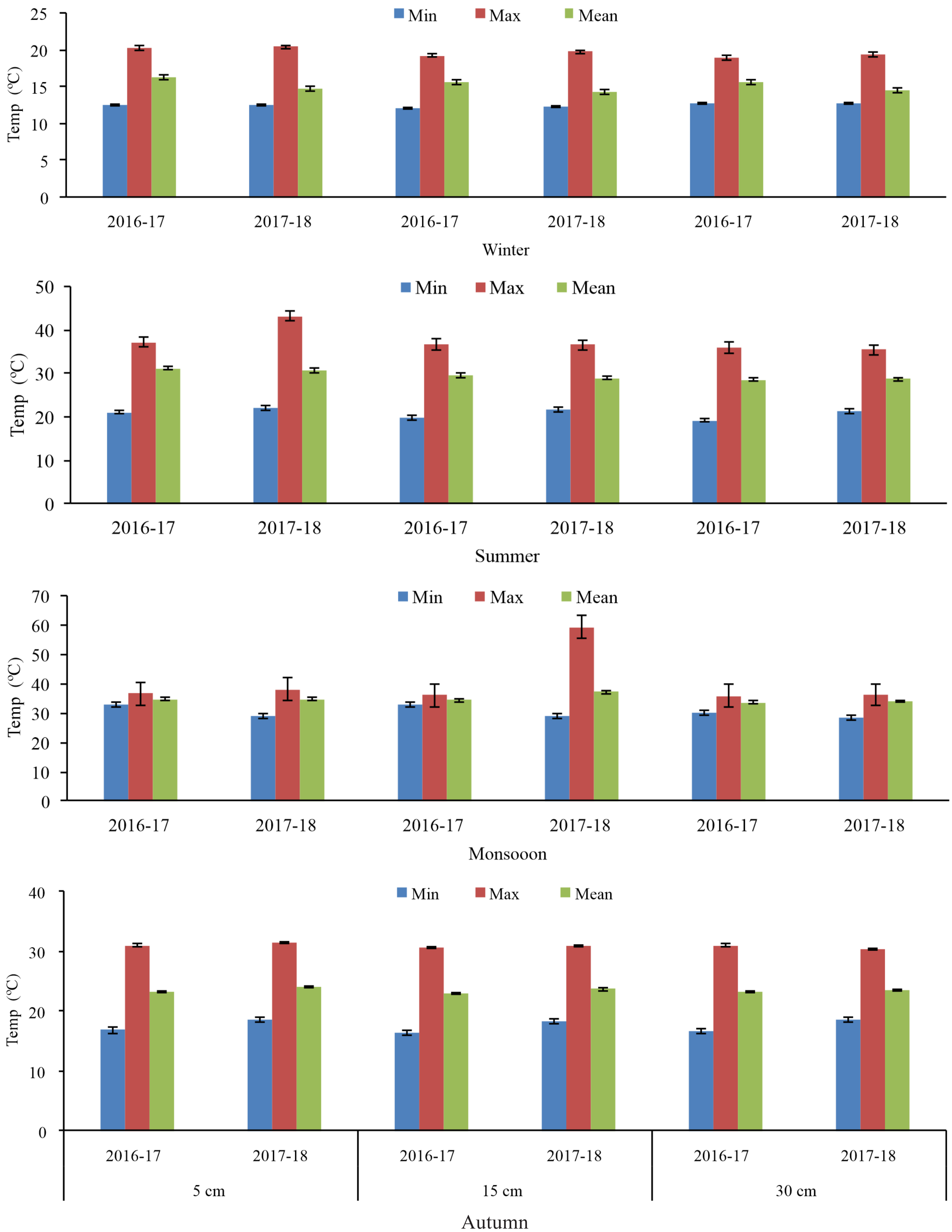

Fig. 2. Variation of seasonal soil temperature at different depth during the study period. Bars represent the standard error of mean

temperature was higher than environmental temperature at all depth. The increase in soil temperature was recorded by 9% in winter, 10% in summer, 15% in monsoon and 8% in autumn, irrespective of soil depth. On an average, the upper soil layer (0-5 cm) showed higher soil temperature (26.2°C) and decease trend was reported with soil depth 5-15cm and 15-30 cm (25.8°C and 25.2°C). It was also observed that all depth soil temperatures were higher during monsoon (34.8°C) followed by summer (29.6°C), autumn (23.4°C) and winter (15.2°C). Soil temperature varies seasonally and daily which may result from changes in radiant energy and energy changes taking place through the soil surface (Onwuka and Mang, 2018). Environmental factors affect soil temperature by either controlling the amount of heat supplied to the soil surface and the amount of heat dissipated from the soil surface down the profile. The temperature of the soil depends on the ratio of the energy absorbed to that lost from the soil (Onwuka and Mang, 2018). It fluctuates annually and daily, affected mainly by variations in air temperature and solar radiation (Wu and Nofziger, 1999). The transfer of heat in the soil (Zhao *et al.*, 2007) and the latent heat exchanges at the surface (Nwankwo and Ogugurue, 2012) are the primary causes of variations in soil temperature.

Soil properties

The $CaCO_3$ content varied from 1.20 to 1.29% with mean value 1.25 % in 0-5 cm. The $CaCO_3$ content was increased with depth and observed 1.40 to 1.56% with mean value 1.49% in 5-15 cm and 2.43 to 2.54% with mean value of 2.51% in 15-30 cm soil (Fig. 3). There is no seasonal variation in $CaCO_3$ content was reported with soil depth. The 0-5 cm soil surface showed low $CaCO_3$ content during all seasons as compared to 5-15 cm and 15-30 cm, might be due to more microbial and plant root activities in upper layer, resulted in release of many organic substances to dissolve $CaCO_3$ (De Vrind-De Jong and De Virnd ,1997, Kawano and Hwang, 2010) and leach down. Many researchers (Landeweert *et al.*, 2001, Sinsabaugh *et al.*, 2002, Van Schöll *et al.*, 2008) reported that plant roots and micro-organisms can release organic acids and enzymes into the soil solution. The result is in order to findings of Yadav and Gupta (2018), who reported low $CaCO_3$ content in surface soils (0-15 cm) as compared 15-30 and 30-60 cm soil layer semi-arid region of Punjab.

The seasonal variation in pH of the soil profile showed that in top soil layer (0-5 cm), the value of pH ranged from 8.07 to 8.17 with mean value of 8.12 (Fig. 4). There is no variation in soil pH observed due to change in season, however soil pH increased with increase in soil depth during all seasons and varies from 8.13 to 8.19 with mean value of 8.16 in subsurface soil (5-15 cm) and from 8.21 to 8.27 with mean value of 8.24 in 15-30 cm soil layer (Fig. 4). The higher pH range of the region might be due to high soil temperature. At a soil temperature (25°C-39°C) the soil pH increases as a result of organic acid denaturation which increases at high temperature (Menzies and Gillman, 2003). The higher pH in lower layers could be due to increase in accumulation of exchangeable cations (Mc Cauley *et al.,* 2017). This finding is in agreement with Yadav and Gupta (2018) who reported increase in soil pH with increase in soil depth under ber (*Ziziphus mauritiana* L.) plants in semi-arid region of Punjab.

The EC varies from 0.34-0.40 dSm^{-1} in surface (0-5 cm) with mean value of 0.36 dSm^{-1}, 0.32-0.35 dSm^{-1} in 5-15 cm soil layer with mean value of 0.33 dSm^{-1} and 0.28-0.29 dSm^{-1} in 15-30 cm soil layer with mean value of 0.29 dSm^{-1} (Fig. 5). The surface soil showed higher EC as compared to subsurface soil (Fig. 5), due to salts released through weathering in the arid/semi-arid regions with limited rainfall are usually deposited at same depth in the soil profile (Rodriguez-Navarro and Doehne, 1999). Similar findings were also reported by Yadav *et al.* (2016) and Yadav and Gupta (2018). The higher soil EC were also reported in summer season, as increased soil temperatures decrease water viscosity, therefore allowing more water to percolate through the soil profile (Broadbent, 2015). In addition, reduced shade combined with increased soil temperatures also results in higher evaporation rates which in

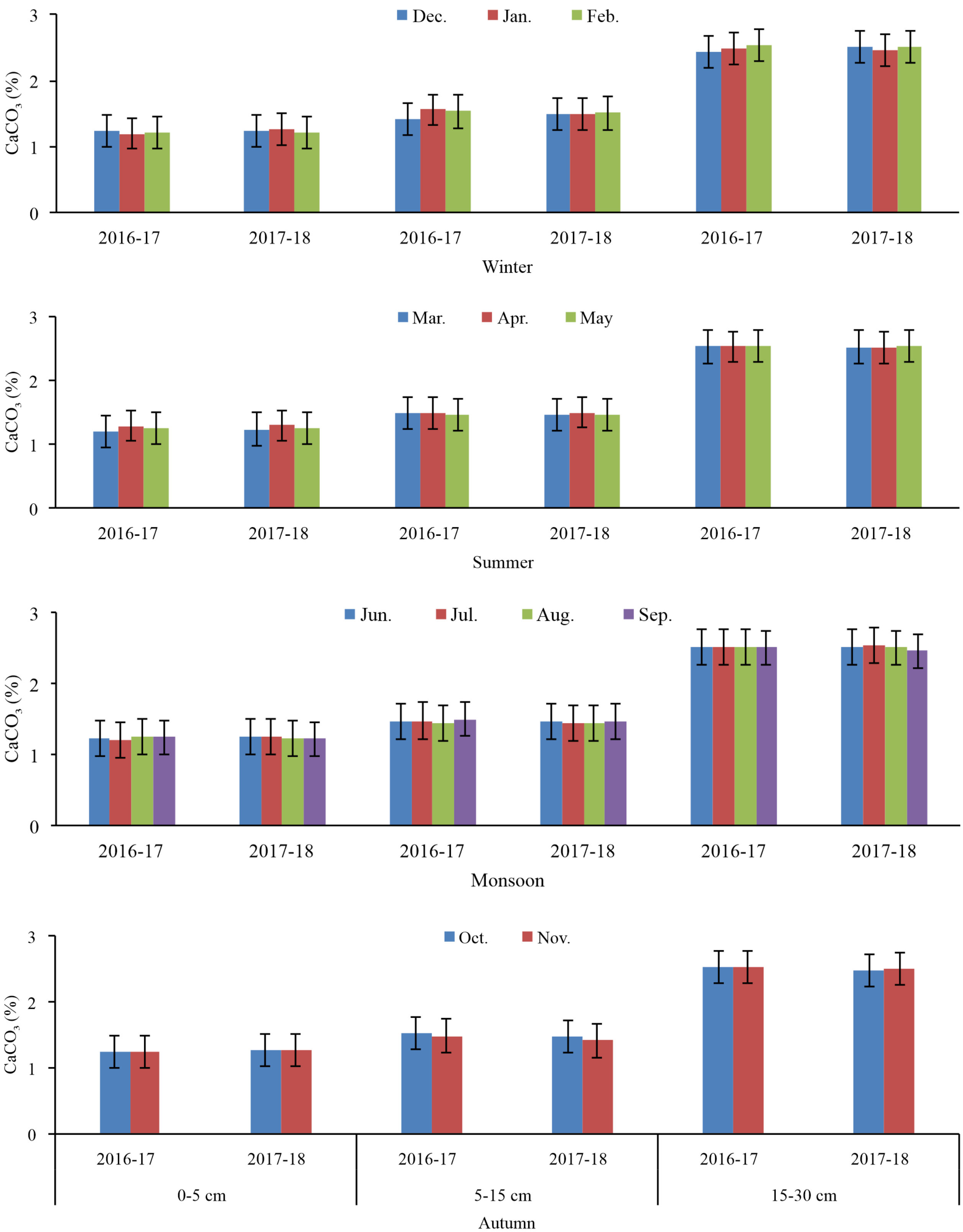

Fig. 3. Variation in seasonal $CaCO_3$ content of soil at different depth during the study period. Bars represent the standard error of mean

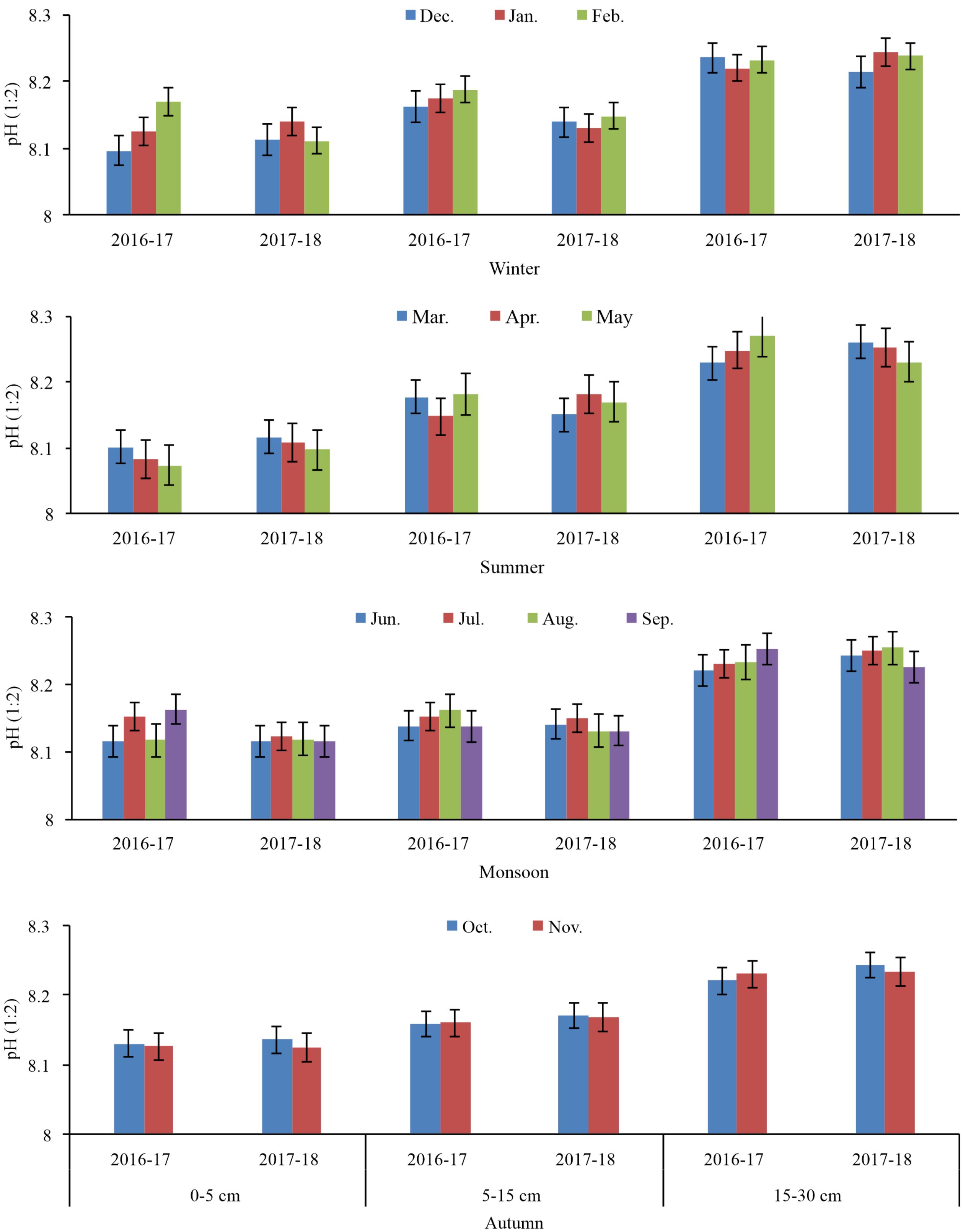

Fig. 4. Seasonal variation in soil reaction (pH) of soil at different depth during the study period. Bars represent the standard error of mean

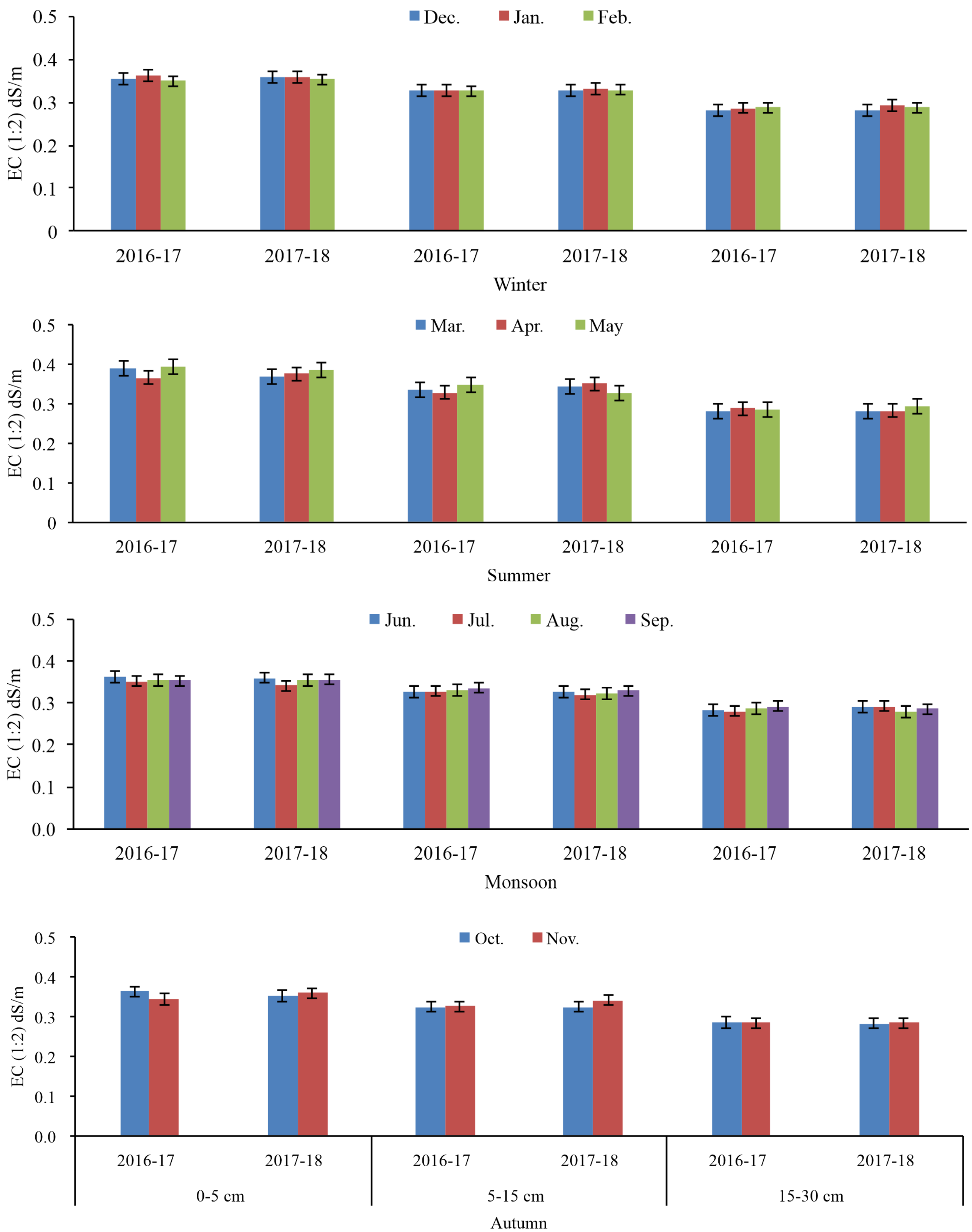

Fig. 5. Seasonal variation in electrical conductivity (EC) of soil at different depth during the study period. Bars represent the standard error of mean

turn restrict the movement of water into the soil profile (Rengasamy and Churchman, 2009) and accumulation of salts on surface soil layer.

Available micronutrients

Seasonal variation in micronutrient availability (Fig. 6) showed that available Fe content of 0-5 cm, 5-15 cm and 15-30 cm soils varied from 4.55 to 4.97 mg kg^{-1}, 4.42 to 4.85 mg kg^{-1} and 3.76 to 4.56 mg kg^{-1} with average values of 4.72 mg kg^{-1}, 4.62 mg kg^{-1} and 4.29 mg kg^{-1}, respectively. Surface soil (0-5 cm) showed 2.2% and 10.0% higher Fe content compared to middle (5-15 cm) and lower (15-30 cm), respectively. Similarly, Fig. 6 revealed that available Cu content varied from 0.68 to 0.85 mg kg^{-1} with mean value of 0.79 mg kg^{-1} in surface soil layers (0-5 cm), while, it varied from 0.43 to 0.51 mg kg^{-1} with mean value of 0.47 mg kg^{-1} in middle surface (5-15 cm) and varied from 0.35 to 0.46 mg kg^{-1} with mean value of 0.42 mg kg^{-1} in lower surface (15-30 cm). A decreased trend of available Cu content in soil was observed with increased in soil depth. The data showed in Fig. 6 indicated that Zn content in soil varied from 0.83 to 0.97 mg kg^{-1}, 0.63 to 0.77 mg kg^{-1} and 0.45 to 0.67 mg kg^{-1} with average values of 0.90 mg kg^{-1}, 0.70 mg kg^{-1} and 0.57 mg kg^{-1} in 0-5 cm, 5-15 cm and 15-30 cm soil layers, respectively. Surface soil (0-5 cm) showed 1.28 times and 1.57 times more Zn content compared to middle (5-15 cm) and lower (15-30 cm), respectively. Available Mn content of 0-5 cm soil ranged from 3.89 to 4.96 mg kg^{-1} with mean value of 4.41 mg kg^{-1}, whereas, in 5-15 cm soil, it varied from 3.41 to 4.18 mg kg^{-1} with a mean value of 3.75 mg kg^{-1} and 15-30 cm soil, it varied from 3.08 to 3.65 mg kg^{-1} with a mean value of 3.44 mg kg^{-1} (Fig. 6). All soil layers contain sufficient amount of Mn as per criteria suggested by Arora (2002). The surface soils showed higher content of Fe, Cu, Zn and Mn than sub-surface soils, which exhibited a decreasing trend with increase in soil depth. Higher Fe in surface soil (0-5 cm) may be due to sufficient organic matter and low pH of surface soils. The surface soils have higher Cu, might be due to higher organic matter and regular addition of manures. The lower depth had less mean DTPA extractable-Cu, which corroborates the observations made by Kher (1993) in an Alfisol and Behera *et al.* (2009) in an Inceptisol. The higher Zn might be due to higher organic carbon at surface soils, as organic carbon is a major contributor of available Zn in soils. The decline in DTPA-extractable Zn may be ascribed to decline in soil organic C content down the soil profile as organic carbon content significantly correlated with DTPA-extractable Zn in surface soil (Behera *et al.*, 2011). The Mn content of surface soils was higher than sub-surface soils and showed a decreased trend with increased in depth which might be due to low pH and high organic matter in surface soil layers. The adequacy of available Mn might be attributed to the positive effect of organic matter and suitable soil pH for Mn availability. Increasing organic matter caused Mn to move from less soluble forms to more plant available forms (Shuman, 1988). These results are in accordance with the observation Sharma *et al.* (2009), that the surface horizons showed relatively higher content of available micronutrient (DTPA-Fe, Cu, Zn and Mn) than the subsurface horizon in salt affected soils of the Punjab. Further, Yadav *et al.* (2016) studied the soil fertility status of PAU seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda, Punjab and reported decreased trends in DTPA-extractable Fe, Cu, Zn and Mn with the increase in soil depth and ranged from 5.25 to 6.25, 0.25 to 0.95, 1.11 to 1.88 and 3.56 to 4.66 mg kg^{-1} with mean value of 5.8, 0.44, 1.51 and 4.09 mg kg^{-1} in 15-30 cm soils. Sadanshiv *et al.* (2017) reported the decreased trends of micronutrients in all the soils of Nagalvadi micro-watershed of Wardha district of Maharashtra with increased in depth of soil profiles. Moreover, Yadav *et al.* (2018a) studied the status of DTPA- extractable micronutrients in soils of Bathinda district of Punjab, India and calculated the nutrient index representing fertility status of soil, showed that the soils were sufficient for supply Fe, Cu, Zn and Mn to crops. Furthermore, Yadav *et al.* (2018b) studied the soil micro-nutrient availability and accumulation in ber (*Ziziphus mauritiana* L.) under semi-arid region and reported higher

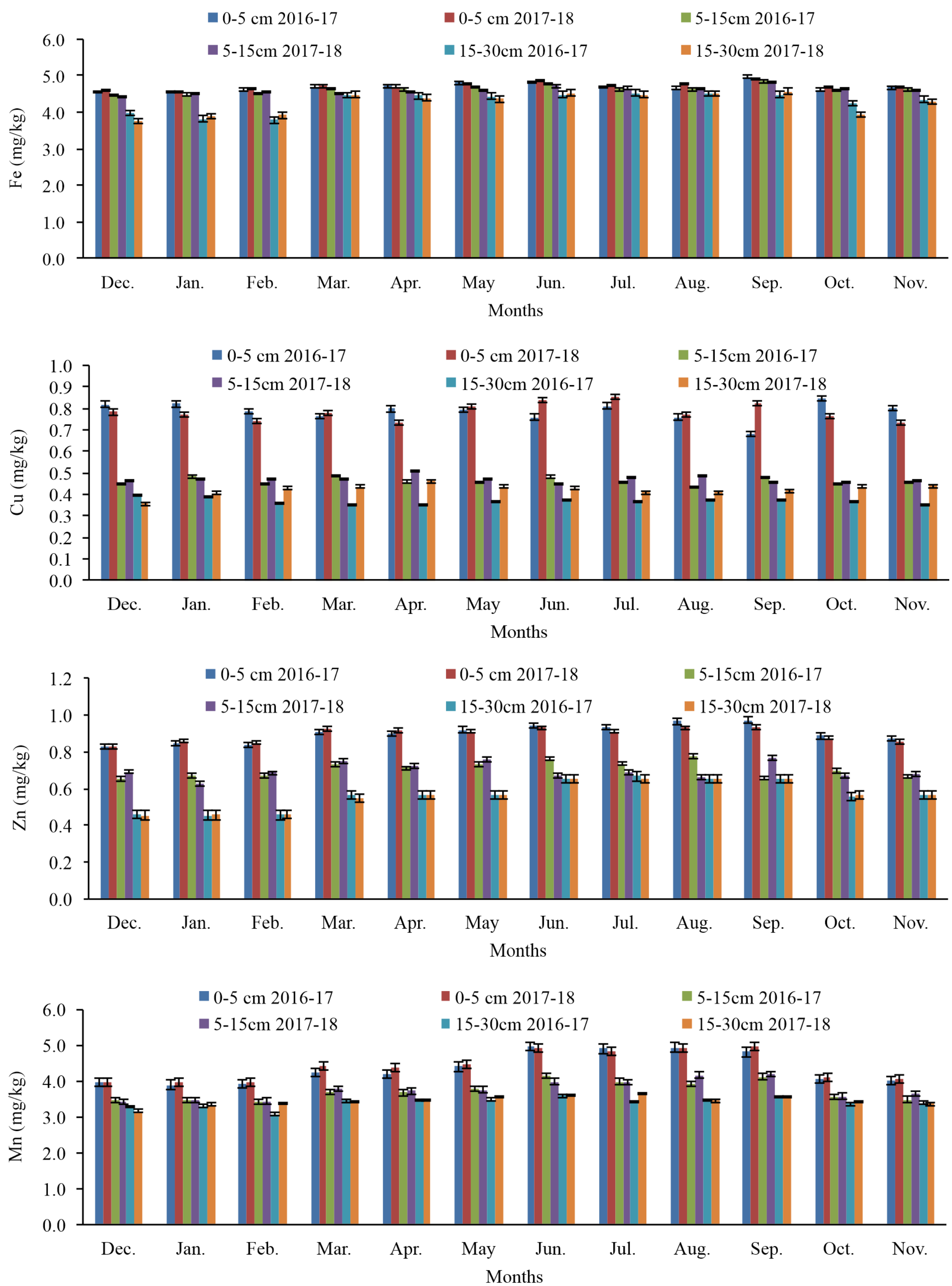

Fig. 6. Seasonal variation in available micronutrients of soil at different depth during the study period. Bars represent the standard error of mean

micronutrient content in surface soils as compared to sub-surface soils. The micronutrients (Fe, Zn and Mn) were higher during the monsoon season followed by summer, autumn and winter. However, no seasonal variation was reported in Cu availability. The higher micronutrient availability in monsoon might be due to higher soil temperature. Higher soil temperature increased the DTPA extractable Fe, Zn and Mn content of soil, as a result of dissolution of minerals due to increased acidity during drying process and also due to decomposition of higher metallo-organic complexes. While, the higher temperature reduced the DTPA extractable Cu, may be due to fixation of soluble Cu by Fe and Al oxides which would be activated by soil heating, as Cu is the most strongly adsorbed of all the divalent metal on Fe and Al oxides (Tisdale *et al.*, 1997).

Conclusion

From the above studies it is concluded that soil temperature showed a strong relationship with the air temperature, which indicates that if air temperature is going to change over the periods, it will have also an impact on soil temperature. Seasonal variation of soil temperature does not affect the soil reaction (pH) and $CaCO_3$ present in soil, whereas, soil temperature influences the soil electrical conductivity (EC) and available micronutrients. Higher soil temperature increases the DTPA extractable Fe, Zn and Mn content of soil, while decreasing trend was reported in Cu availability. The upper soil surface (0-5 cm) showed higher content of Fe, Cu, Zn and Mn than sub-surface (5-15 cm) and (15-30 cm) and a decreased trend was reported with increase in soil depth. The micronutrients (Fe, Zn and Mn) availability was higher during the monsoon season followed by summer, autumn and winter. However, no seasonal variation was reported in Cu availability.

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