MAUSAM, **73**, 2 (April 2022), 405-412

MAUSAM

DOI : https://doi.org/10.54302/mausam.v73i2.5483
Homepage: https://mausamjournal.imd.gov.in/index.php/MAUSAM

UDC No. 631.433.5 : 631.445.5 : 634.13

Effect of weather variability on soil temperature, enzyme activities and nutrient availability under pear tree orchard in semi arid condition

B. K. YADAV and R. K. PAL*

Punjab Agricultural University, Regional Research Station, Bathinda – 151 001, Punjab, India

**Department of Climate Change and Agricultural Meteorology,*

Punjab Agricultural University, Ludhiana – 141 004, Punjab, India

(*Received 13 June 2020, Accepted 24 December 2021*)

e mail : bkyadav74@pau.edu

सार – पंजाब के बठिंडा जिले की अर्ध-शुष्क स्थिति में शुष्क मृदा में मृदा तापमान, एंजाइम गतिविधियों और पोषक तत्वों की उपलब्धता पर मौसम परिवर्तनशीलता के प्रभाव को मापने के लिए वर्तमान अध्ययन किया गया है। इस संदर्भ में, मृदा के नमूने साप्ताहिक आधार परलगातार तीन वर्षों (2016-2018) तक नाशपाती के पेड़ (पाइरस कम्युनिस एल.) के बाग से तीन गहराईयों पर: 0-5 सेमी (शीर्ष), 5-15 सेमी (मध्य) और 15-30 सेमी (निचले) से यादृच्छिक रूप से एकत्र किए गएऔर संबंधित गहराईयों के लिए मृदा तापमान का प्रेक्षण किया गया। मृदा में जैविक कार्बन की मात्रा का मान मृदा की गहराई में वृद्धि के साथ घटता गया और मध्यम तथा निचली गहराई में क्रमशः 24 और 40 प्रतिशत कम जैविक कार्बन की मात्रा पाई गई। इसी तरह, 0-5 सेमी मृदा की गहराई पर भी पोटैशियम(के) की मात्रा अधिक पाई गई और यह गहराई के साथ घटती गई। जबकि 5-15 सेंटीमीटर मृदा की गहराई पर डिहाइड्रोजिनेज, अम्ल और क्षारीय फॉस्फेट एवं फॉस्फोरस(पी)का मान अधिक पाया गया। इसके अलावा, पोषक तत्वों (पी और के) की उपलब्धता 2017 में अधिक और उसके बाद 2018 तथा 2016 में थोड़ी और अधिक पाई गई। वैकल्पिक रूप से, 2016 के दौरान सामान्य से अधिक से भारी वर्षा तक की गतिविधियों के कारण, मृदा के पोषक तत्व बाकी वर्षों की तुलना में ऊपरी परतों से कम हो गए। इसके अतिरिक्त, मृदा की गहराई और अध्ययन के वर्षों में, मृदा का तापमान हवा के तापमान से अधिक पाया गया। जांच के दौरान मृदा एंजाइम गतिविधियों और पोषक तत्वों की उपलब्धता में कम विचलन वर्ष 2016 में तथा बाद के वर्ष 2017 और 2018 में पाए गए, इसी तरह, मौसम प्राचलों के संबंध में बाकी वर्षों की तुलना में 2016 में भी कम विचलन पाए गए। मृदा की गहराई और अध्ययन के वर्षों में, हवा और मृदा के तापमान के बीच सहसंबंध गुणांक (आर) मान 1% के संभावना स्तर पर सकारात्मक और महत्वपूर्ण पाया गया। हालांकि, तेज धूप और वर्षा बनाम मृदा तापमान के संबंध में 2018 की वर्षा को छोड़कर गैर-महत्वपूर्ण लेकिन सकारात्मक सहसंबंध पाए गए जो महत्वपूर्ण थे।

ABSTRACT. The present study was conducted to quantify the effect of weather variability on soil temperature, enzyme activities and nutrient availability in arid soil under semi arid condition of Bathinda district of Punjab. In this context, soil samples were collected on weekly basis for three consecutive years (2016-2018) randomly from pear tree (*Pyrus communis* L.) orchard at three depths: 0-5 cm (top), 5-15 cm (middle) and 15-30 cm (lower), while, soil temperature observations for the respective depths were taken. The value of organic carbon content in soil decreased with increased in soil depth and reported 24 and 40 per cent lower organic carbon in middle and lower depths, respectively. Similarly, K content was also found more at 0-5 cm soil depths and decreased with depth. While, the value of dehydrogenase, acid and alkaline phosphatase and P was found more at 5-15 cm soil depth. Furthermore, nutrients (P and K) availability was found slightly higher in 2017 followed by 2018 and 2016. Alternatively, due to more moderate to heavy rainfall activities during 2016, soil nutrients were leached down from upper layers than rest years. Additionally, among the soil depths and years of study, soil temperature was watched higher than air temperature. Lesser deviations in soil enzyme activities and nutrient availability were found during the investigation year of 2016 followed by 2017 and 2018, likewise, lesser deviations were additionally found in 2016 than rest of the years in regard of weather parameters. Among soil depths and years of study, correlation coefficient (r) value between air and soil temperature was found positive and significant at 1% probability level. However, In respect of bright sunshine and rainfall vs. soil temperature, non-significant but positive correlation was found except 2018 for rainfall which was significant.

Key words – Weather variability, Soil temperature, Nutrient availability, Soil enzyme activities.

1. Introduction

Weather variability and the increase of extreme weather events undoubtedly have an adverse impact on soil health and agricultural production (Liu and Basso, 2020). The local weather exchanges immediately affect the future food availability and enlarge the situation of feeding the fast growing world's population. Temperature and precipitation are the most vital weather variables that are regularly used to quantify magnitude of local weather exchange and variability (IPCC, 2007). The raised temperature under global climate change ends up in quicker crop development that reflects in yield declines and faster soil carbon mineralization (Basso *et al.*, 2018). The global climate change entails changes in climate variability and within the frequency of excessive weather events. To curb the impact of weather variability, adaptation strategies need to be developed and evaluated. Global climate change has an effect on the soil, a significant component in agricultural system. Higher air temperatures cause higher soil temperatures, that usually will increases solutions chemical reaction rate and diffusion controlled reactions (Buol *et al.*, 1990). The soil temperature regime is ruled by gains and losses of sun radiation at the surface, the method of evaporation, heat transmission through the soil profile and convective transfer *via* the movement of gas and water (Karmakar *et al.*, 2016). As with soil moisture, soil temperature is a prime mover in most soil processes. Warmer soil temperature will accelerate soil processes, rapid decomposition of organic matter, increased microbiological activity (Patil and Lamnganbi, 2018).

The soil enzymes play key biochemical processes in overall procedure of organic matter decomposition in the soil system and have shown to be sensitive indicators of environmental changes (Burns *et al*., 2013). It may be influenced by alternative factors like soil pH, moisture content in soil, substrate availability and soil temperature. These factors may have an effect soil microbes community (size/composition) and thus changes within these variables will have an effect on overall enzyme production that alters the metabolic processes in the soils (Adetunji *et al.*, 2017).

Particularly, temperature may be an issue that influences the rates of enzyme catalysis, enzyme production and organic compound alteration rates within the ecosystems (Wallenstein *et al*., 2011). The dehydrogenase enzyme is usually used as an indicator of biological activity in soils (Burns, 1978) and better known to oxidise soil organic matter by transferring protons and electrons from substrates to acceptors. Dehydrogenase enzyme activities study within the soil is extremely necessary because it offer indications of the potential of the soil to support biochemical processes that are necessary for maintaining the soil fertility. In particular, nutrient uptake is affected by soil temperature (Xu and Huang, 2006). Soil temperature may influence the physico-chemical and biological processes which affect nutrient availability in soils and in turn affect plant nutrient uptake (Hussain and Maqsood, 2011). Clarkson *et al.* (1992) reported that specific absorption rates of plant nutrients depended on soil temperature to a large extent; even a small raise in soil temperature could induce large changes in plant growth and nutrient absorption. Giovannin *et al.* (1990) reported that increased in soil temperature induced mineralization of organic P and release of absorbed P as well as supply of P. Similarly, due to heating K is also released from lattice layers of K bearing minerals present in the soil.

The assessment of enzymes activities and their temperature dependence is useful to understand how abiotic changes in soils can affect the nutrient cycling in soil. Considering that the enzymes are an integral part of C and N cycling in soil organic matter, it was hypothesized that they could be used to evaluate the dynamics and role of soil carbon in response to increases in temperature. Therefore, the study was carried out to determine the response of weather variability on soil temperature, enzyme activities and nutrient availability under pear tree orchard in semi arid condition.

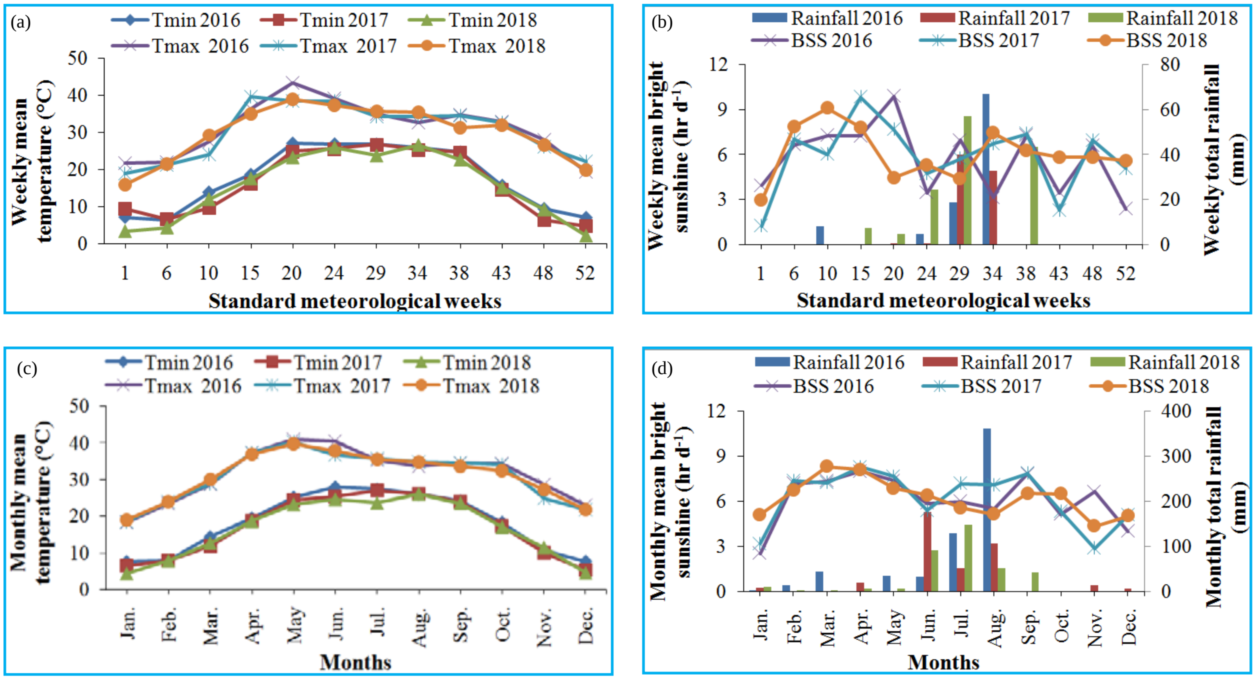
2. Materials and method

2.1. *Characteristics of the study site*

The Bathinda district lies in the extreme South-West part of Punjab and in far away from the Shivalik ranges in the North of the state. The annual normal rainfall of this region is about 436 mm, 80 percent of which is received during the south-western monsoon season (First week of July to mid September) and remaining during the winter season. Dust storms are a regular feature in summer season when the mercury sometime touches over 47.0 °C in the peak summer in May-June, however, in winter during December and January, the minimum temperature at night could touch 0.0 °C. The climate of the area is characterized by a large seasonal variation as well as fluctuations both in monthly rainfall and temperature.

2.2. *Soil temperature and agro-meteorological observations*

Soil temperature was recorded for the study period of 2016, 2017 and 2018 at three depths, *viz.*, 5 cm, 15 cm and 30 cm randomly from pear tree (*Pyrus communis* L.) orchard using dial gauge soil thermometer. The mean soil temperature observations were used for further analysis.



Figs. 1(a-d). Characteristics of weekly mean minimum and maximum temperatures (a), weekly mean bright sunshine and total rainfall, (b) monthly mean minimum and maximum temperatures, (c) and monthly mean bright sunshine and total rainfall and (d) during the study period of 2016, 2017 and 2018

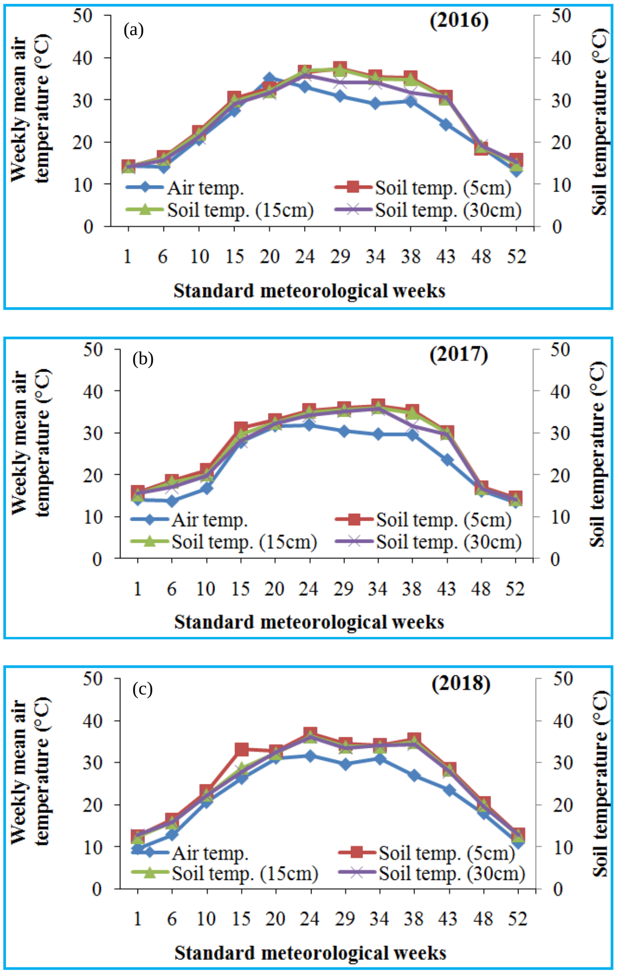
Moreover, minimum and maximum temperature, morning and evening relative humidity, evaporation and rainfall observations were recorded from Agrometeorological Observatory of PAU Regional Research Station, Bathinda for the study year of 2016, 2017 and 2018.

During study period, among the respective weeks of soil sampling observations, mean value of minimum air temperature (T_{min}) and maximum air temperature (T_{max}) was found higher in the study year of 2016 (17.4 and 31.1 °C) than by 2017 (16.1 and 30.4 °C) and 2018 (15.6 and 29.7 °C) [Fig. 1(a)] and also followed the trend of monthly mean value for air temperature [Fig. 1(c)]. Moreover, during study period of 2016, 2017 and 2018, weekly sunshine was recorded in the range between 2.4-9.9, 1.2-9.8 and 2.9-9.1 hours/day, respectively [Fig. 1(b)]. A total of 619.0, 388.3 and 364.1 mm rainfall were received in the study region during 2016, 2017 and 2018, respectively [Fig. 1(d)], while, in respect of observations week of soil sampling, higher rainfall was received during 2018 (136.2 mm) followed by 2016 (98.5 mm) and 2017 (73.7 mm).

2.3. *Soil sampling and analysis*

The soil of the study area is sandy loam with sand, silt and clay content of 79.63 percent, 12.11 percent and 8.26 percent, respectively having bulk density of 1.52 g cm^{-3}. The soil samples were collected on weekly basis for three consecutive years (2016-2018) randomly under pear tree (*Pyrus communis* L.) orchard at three depths : 0-5 cm, 5-15 cm and 15-30 cm with the help of auger. The soils from 4 sides of the trunk under the plant canopy were collected, mixed and prepared a composite sample of each depth, placed in labelled plastic bags and transferred immediately to the laboratory. The samples were passed through 2-mm sieve and divided into two fractions: one fraction for the determination of chemical fractions, which was kept at room temperature and the other fraction for measuring of soil enzyme activities which was stored at 4 °C.

Dehydrogenase activity (DHA) of soil was determined using the reduction of 2, 3, 5-triphenyltetrazolium chloride (TTC) method (Klein *et al.*, 1971) and the colour intensity was measured at 485 nm by spectrophotometer. The DHA was expressed as microgram (µg) triphenylformazane (TPF) produced per gram (g) dry soil per hour at 37 °C. Acid and alkaline phosphatase activity were estimated using the method reported by Tabatabai and Bremner (1969) and expressed as microgram (µg) ρ-nitro phenol produced per gram (g) dry soil per hour. After soil incubation with modified universal buffer (pH 6.5 for acid phosphatase and pH 11.0 for alkaline phosphatase) and p-nitrophenyl phosphate (ρ-NP) at 37 °C, the produced yellow colour intensity was measured colorimetrically at 440 nm. The organic carbon was determined by wet



Figs. 2(a-c). Meteorological conditions in respect of weekly mean air temperature and soil temperature at different depths during the study period of 2016, 2017 and 2018

digestion method (Walkley and Black, 1934). The available P in the soil was extracted by employing Olsen extractant (0.5 M $NaHCO_3$, pH 8.5) as described by Olsen *et al.* (1954). The available K was extracted by using neutral ammonium acetate and the content was determined by aspirating the extract into flame photometer (Jackson, 1973). Fertility status of macro-nutrients is interpreted as the criteria suggested by Arora (2002).

2.4. *Analysis of experimental data*

For the statistical analysis of data, Microsoft Excel software (Microsoft Corporation, USA) have been used. Additionally, correlation coefficients value were calculated between weekly mean air temperature *vs.* soil temperature, bright sunshine *vs.* soil temperature and rainfall *vs.* soil temperature at 5 cm, 15 cm and 30 cm soil depths and checked their significance level at 5 and 1 per cent probability level.

3. Results and discussion

3.1. *Mean air temperature vs. soil temperature*

The mean air temperature and soil temperature at various depths *i.e.*, 5 cm, 15 cm and 30 cm recorded at different standard meteorological weeks during the study years 2016, 2017 and 2018 have been illustrated in Figs. 2(a-c). During study period, mean air temperature deviated in the range from 13.2 - 35.2 °C, 13.4 - 32.0 °C and 9.6 - 31.6 °C in 2016, 2017 and 2018, respectively. Soil temperature at 5 cm depth varied in the range from 14.2 - 36.6 °C, 14.3 - 35.5 °C and 12.1 - 35.8 °C in 2016, 2017 and 2018, respectively. While, soil temperature of 15 cm depth varied in the range from 14.2 - 36.9 °C, 13.8 - 35.0 °C and 11.7 - 35.3 °C in 2016, 2017 and 2018, respectively. Similarly, soil temperature of 30 cm depth ranged from 12.1 - 35.2 °C, 13.8 - 34.1 °C and 14.1 - 35.9 °C in 2016, 2017 and 2018, respectively. Variation in soil temperature, physico-chemical and micronutrients availability in soils of Pear (*Pyrus communis* L.) under semi-arid environment was also studied by Yadav and Gupta (2019) and reported that the upper soils layer (0-5 cm) showed higher soil temperature and decrease with increase in depth.

Among the year of study, soil temperature recorded at all the depths of 5, 15 and 30 cm was found higher than the weekly mean air temperature. Similarly, Yadav and Gupta (2019) also reported that the higher soil temperature values than environmental temperature. Among the years, lesser variation in mean air temperature was recorded in the study year 2017 than the rest of the years, while, lower value of air temperature was observed during 2018. A similar trend was also found in respect of soil temperatures recorded at 5 cm, 15 cm and 30 cm depths as mean air temperature, lesser variation was observed in 2017 followed by 2016 and 2018. The higher soil temperature was recorded at upper soil layer (0-5 cm) and decreased with increased in soil depth with lesser variations (Fig. 2). During study period, higher value of mean air temperature was recorded during 2016 (24.2 °C) followed by 2017 (23.3 °C) and 2018 (22.6 °C) and similar trend was also observed for soil temperatures recorded at all the depths. Alternatively, among the soil depths, higher value of soil temperature was observed in the study year of 2016 (26.0 - 26.7 °C) followed by 2017 (25.2 - 26.3 °C) and 2018 (25.1 - 25.5 °C). The correlation coefficient (r) value between air and soil temperature was found positive and significant at 5% and 1% probability level at 5 cm depth, 15 cm depth and at 30 cm depth (Table 1). In respect of bright sunshine *vs.* soil temperature at all the depths, non-significant but positive correlation was found during the study years of 2016, 2017 and 2018. Additionally, higher correlation values were observed at 5 cm soil depth than others (Table 1).

TABLE 1

Correlation values between mean air temperature, bright sunshine and rainfall *vs.* soil temperature at various depths during study periods of 2016, 2017 and 2018

Years	Mean air temperature			Bright sunshine			Rainfall		
	5 cm	15 cm	30 cm	5 cm	15 cm	30 cm	5 cm	15 cm	30 cm
2016	0.987**	0.989**	0.989**	0.314	0.310	0.284	0.305	0.308	0.312
2017	0.991**	0.992**	0.989**	0.371	0.346	0.307	0.433	0.454	0.490
2018	0.993**	0.991**	0.990**	0.037	0.031	0.028	0.541*	0.564*	0.576*

Significant at 5 (*) and 1 (**) percent Probability level

TABLE 2

Organic carbon (percent) status in soil at different depths during the study period

Soil depth STW*	0-5 cm			5-15 cm			15-30 cm		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
1	0.45	0.45	0.46	0.38	0.37	0.37	0.34	0.35	0.34
6	0.46	0.47	0.46	0.37	0.37	0.37	0.34	0.34	0.33
10	0.47	0.46	0.48	0.36	0.37	0.37	0.34	0.34	0.33
15	0.47	0.48	0.48	0.36	0.36	0.37	0.34	0.34	0.34
20	0.47	0.47	0.47	0.37	0.37	0.37	0.34	0.34	0.34
24	0.47	0.46	0.47	0.37	0.37	0.37	0.33	0.34	0.33
29	0.46	0.46	0.48	0.36	0.37	0.37	0.32	0.33	0.33
34	0.47	0.47	0.47	0.35	0.36	0.36	0.33	0.34	0.33
38	0.47	0.47	0.47	0.37	0.36	0.37	0.33	0.34	0.34
43	0.46	0.46	0.46	0.36	0.37	0.37	0.33	0.34	0.34
48	0.47	0.47	0.47	0.37	0.37	0.37	0.32	0.33	0.33
52	0.46	0.46	0.47	0.36	0.36	0.36	0.32	0.33	0.34

*Standard Meteorological weeks

Alternatively, in respect of rainfall *vs*. soil temperature, among the soil depths, non-significantly positive correlation was found during 2016 and 2017, while, significantly positive correlation was observed during 2018 at 5 percent Probability level. Moreover, rainfall vs. soil temperature at 30 cm depth indicated higher correlation value than other soil depths in all the years of study (Table 1).

3.2. *Organic carbon*

The value of organic carbon (OC) content varied in the range from 0.45 to 0.48, 0.35 to 0.38 and 0.33-0.35 percent with an average of 0.34 percent at upper (0-5 cm), middle (5-15 cm) and lower (15-30 cm) soil depths, respectively (Table 2), while, among years, no significant variations have been found. The value of organic carbon content in soil decreased with increased in soil depth and reported 24 and 40 percent less organic carbon in middle and lower soil layers over top. In respect of observation weeks, upper soil layers (0-5 cm) showed slightly higher OC in the year 2018 than rest of the years. However, no significant differences in OC variables were recorded according to standard meteorological weeks. This may be due to more moderate to heavy rainfall activities during 2016, which leads to soil nutrients were leached down from upper layers than rest years. The results are in line with finding of Yadav *et al.* (2018), who reported medium to high OC under ber (*ziziphus mauritiana* L.) plants in semi-arid region of Punjab and decreased with increased in soil depth. The data also showed that the soil of orchard is having medium to high level of organic carbon, which needs proper management of nutrients like application of FYM etc. at the time of pruning and other nutrient by time to time as per soil testing.

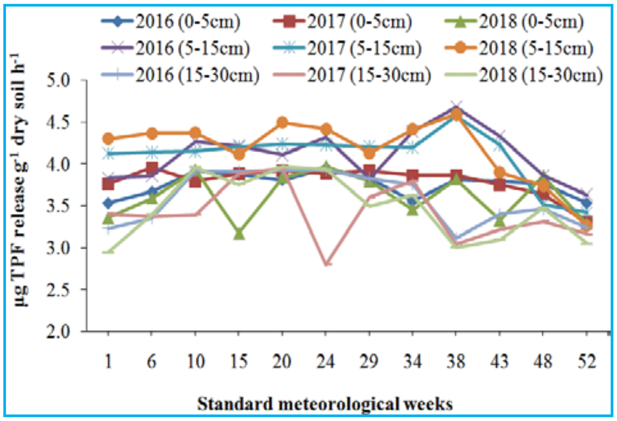


Fig. 3. Dehydrogenase activity of soil at different depths during the study period of 2016, 2017 and 2018

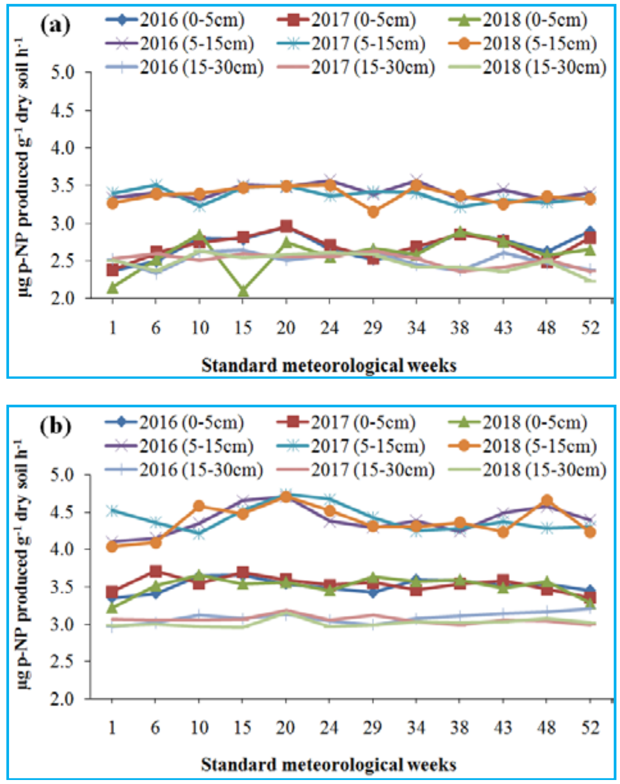
3.3. *Soil enzymes activity*

3.3.1. *Dehydrogenase activities (DHA)*

In general, among the years, more dehydrogenase activities (DHA) was found at 5-15 cm soil depth followed by 0-5 cm and 15-30 cm depths and indicated 10-15 percent and 15-20 percent lesser DHA at top (0-5 cm) and lower (15-30 cm) depths, respectively. Moreover, more DHA was observed during the study year of 2016 (3.12 - 4.68 µg TPF release g^{-1} dry soil h^{-1}) followed by 2017 and 2018 with marginal changes in value (Fig. 3). DHA in soil depends on the content of soluble organic carbon and, the increased organic matter enhances the soil enzyme activities (Nannipieri *et al.*, 2012). Furthermore, in middle soil layer the soil temperature is also stable compared to top layer, with organic carbon, cause favourable conditions to microbes to maintain their population and increase DHA. This result is in agreement with the observation made by Yadav *et al.* (2018), who reported higher DHA in surface soils (0-15 cm) compared to subsurface layers (15-30 cm) and (30-60 cm) under ber (*ziziphus mauritiana* L.) plants in semi-arid region of Punjab.

3.3.2. *Acid and alkaline phosphatase activities*

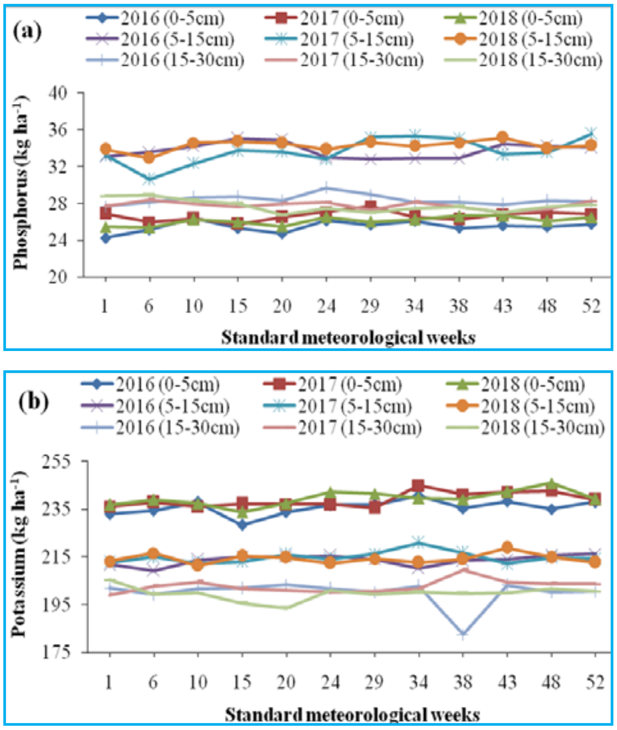
The acid and alkaline phosphatase activities during study period from 2016-2018 have been illustrated in Figs. 4 (a&b), respectively. The acid phosphatases varied in the range between 2.33-3.57, 2.35-3.51 and 2.11-3.51 µg p-NP produced g^{-1} dry soil h^{-1} during 2016, 2017 and 2018, respectively. While, among the years, mean value indicated higher acid phosphatases at middle soil depth (2.51-3.42 µg p-NP produced g^{-1} dry soil h^{-1}) followed by upper (2.59-2.70 µg p-NP produced g^{-1} dry soil h^{-1}) and lower depths (2.51-2.48 µg p-NP produced g^{-1} dry soil h^{-1}). Similarly, alkaline phosphatases



Figs. 4(a&b). Acid phosphatase (a) and alkaline phosphatase and (b) activity of soil at different depths during the study period of 2016, 2017 and 2018

varied between 3.35-3.71, 4.11-4.74 and 2.96-3.21 µg p-NP produced g^{-1} dry soil h^{-1} during 2016, 2017 and 2018, respectively, while, mean value indicated higher alkaline phosphatases at middle soil depth (4.39 - 4.73 µg p-NP produced g^{-1} dry soil h^{-1}) followed by upper (3.51-3.54 µg p-NP produced g^{-1} dry soil h^{-1}) and lower depths (3.02-3.09 µg p-NP produced g^{-1} dry soil h^{-1}).

Among the years of study, the middle and top soil layers showed 25-27 percent and 34-36 percent more acid phosphatase as well as 24-25 percent and 42-42 percent more alkaline phosphatase in respect of lower soil layer, respectively. Besides of that, the alkaline phosphatase activity was observed more compared to acid phosphates as alkaline reaction of the soil might also have increased alkaline phosphatase activity, moreover, pH of the soil solution exerts strong control on enzyme activities (Chhonkar *et al.*, 2007). Yadav *et al.* (2018) have also reported higher alkaline phosphatase compared to acid phosphatase under ber (*ziziphus mauritiana* L.) orchard. Moreover, the more phosphatases activity was reported in 2017 followed by 2016 and 2018, might be due to less variation in air temperature during study year of 2017 (14.5-36.5 °C) than 2016 (14.2-37.5 °C) and 2018 (12.5-36.9 °C).



Figs. 5(a&b). Available phosphorus (a) and potassium and (b) in soil at different depth during the study period of 2016, 2017 and 2018

3.4. *Soil nutrient availability*

3.4.1. *Available phosphorus (P)*

The availability of phosphorus (P) as affected by weather variability and soil temperature has been illustrated in the Fig. 5(a). The available P in soil varied from 24.26-27.68, 30.64-35.56 and 26.74-29.68 kg ha^{-1} during 2016, 2017 and 2018, respectively. While, among depths of soil, higher value of available P was observed at middle soil depth (33.69-34.28 kg ha^{-1}) followed by lower (27.73-28.40 kg ha^{-1}) and upper depths (25.50-26.64 kg ha^{-1}). According to meteorological weeks, the P availability was slightly higher during 24 to 34 weeks, whereas no significant differences were recorded during entire study period. Medium P content was recorded during the entire study period from pear orchard. Moreover, middle soil layer indicated 26-32 percent and 15-23 percent more P compare to top and lower soil layers, respectively, may be due to higher alkaline phosphatase activities which mineralize organically bound P. The data suggested that phosphomonoesterases originating from either plant roots or, micro-organisms had the potential for enhancing P availability. Medium to high P content in soils of arid tract of Punjab has been also reported by Verma *et al.* (2005). Similarly, Yadav *et al.* (2016) have also reported medium P content in soils of Bathinda and higher available P at 15-30 cm soil depth followed by 15-30 cm and 30-60 cm under ber (*ziziphus mauritiana* L.) orchard in semi-arid region of Punjab (Yadav *et al.*, 2018). Furthermore, available P is slightly higher during study year of 2017 followed by 2018 and 2016, may be due to more variation in maximum temperature during 2017 (19-41 °C) followed by 2018 (16-37 °C) and 2016 (22-40 °C). Giovannini *et al.* (1990) stated that increase in temperature helps induced mineralization of organic P and release of absorbed P in the soil.

3.4.2. *Available potassium (K)*

The availability of potassium (K) as affected by weather variability and soil temperature has been illustrated in the Fig. 5(b). The available K in soil varied from 182.57-240.71, 199.02-245.0 and 193.67-245.96 kg ha^{-1} during 2016, 2017 and 2018, respectively. While, among depths of soil, higher value of available P was observed at upper soil depth (228.50-240.71 kg ha^{-1}) followed by middle (209.39-245.0 kg ha^{-1}) and lower depths (182.57-245.96 kg ha^{-1}). Although, the K content was found decreased with depth, but no deficiency was reported in soil during the study period, due to prevalence of Illite - A potassium rich mineral in these soils. Moreover, as the ground water of south-western district having considerable amount of dissolved K, irrigation with such water also resulted higher available K in the soil. These finding are also in line as reported by Patel *et al.* (2000), Verma *et al.* (2005), Yadav *et al.* (2016) and Yadav *et al.* (2018). Like available P, available K was also found slightly higher during 2017 followed by 2018 and 2016, might be due to having higher soil temperature during 2017, potassium is released from lattice layers of K bearing minerals present in the soil.

4. Conclusions

The variability in air temperature, bright sunshine and rainfall influence soil temperature, which is one of the most important abiotic factors for altering enzyme activity and nutrient availability in the soil. During the study's years, soil temperatures were found to be higher than air temperatures. Furthermore, a declining tendency in soil temperature was found as soil depth increased. In addition, 15 cm and 30 cm soil depths had 1.6 percent and 2.9 percent lower soil temperatures, respectively, than 5 cm soil depth. Moreover, when compared to 5-15 cm and 15-30 cm soil layers, upper (0-5 cm) soil layers had 24 percent and 38 percent higher soil organic carbon and 9 percent and 18 percent higher K content, respectively. The middle (5-15 cm) soil layers had 5, 27, 25, 30 percent more dehydrogenase, acid phosphatase, alkaline phosphatase and phosphorus than the upper (0-5 cm) and lower (15-30 cm) soil layers, respectively. Lesser variances in soil enzyme activity and nutrient availability were reported in 2016 compared to 2017 and 2018 and similarly, less deviation in meteorological parameters was found in 2016 compared to the other years. In view of the fact, soil nutrients and enzyme activities are considered to be important component for crop production, which influenced significantly with weather variability under semi arid conditions.

Acknowledgement

Authors are thankful to Director, PAU Regional Research Station, Bathinda for providing all facilities to carry this study.

Disclaimer : The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

Adetunji, A. T., Lewu, F. B., Mulidzi, R. and Ncube, B., 2017, "The biological activities of β-glucosidase, phosphatase and urease as soil quality indicators : a review", *Journal of Soil Science and Plant Nutrition*, **17**, 794-807.

Arora, C. L., 2002, "Analysis of soil, plant and Fertilizer. In : Fundamentals of Soil Science", *Indian Society of Soil Science*, p548.

Basso, B., Dumont, B., Maestrini, B., Shcherbak, I., Robertson, G. P., Porter, J. R., Smith, P., Paustian, K., Grace, P. R., Asseng, S., Bassu, S., Biernath, C., Boote, K. J., Cammarano, D., De Sanctis, G., Durand, J.L., Ewert, F., Gayler, S., Hyndman, D. W., Kent, J., Martre, P., Nendel, C., Priesack, E., Ripoche, D., Ruane, A.C., Sharp, J., Thorburn, P. J., Hatfield, J. L., Jones, J. W. and Rosenzweig, C., 2018, "Soil organic carbon and nitrogen feedbacks on crop yields under climate change", *Agricultural and Environmental Letters*, https://doi.org/10.2134/ael2018.05.0026.

Buol, S. W., Sanchez, P. A., Kimble, J. M. and Weed, S. B., 1990, "Predicted impact of climatic warming on soil properties and use", *American Society of Agronomy*, **53**, 71-82.

Burns, R. G., 1978, "Enzyme activity in soil : some theoretical and practical considerations", In : Bums RG (ed) Soil enzymes. Academic, London, 295-340.

Burns, R. G., De Forest, J. L., Marxsen, J., Sinsabaugh, R. L., Stromberger, M. E., Wallenstein, M. D., Weintraub, M. N. and Zoppini, A., 2013, "Soil enzymes in a changing environment: current knowledge and future directions", *Soil Biology and Biochemistry*, **58,** 216-234.

Chhonkar, P. K., Bhadraray, S., Patra, A. K. and Purakayastha, T. J., 2007, "Experiments in Soil Biology and Biochemistry", Westville Publishing House, New Delhi, India.

Clarkson, D. T., Jones, L. H. P. and Purves, J. V., 1992, "Absorption of nitrate and ammonium ions by Lolium perenne from flowing solution cultures at low root temperatures", *Plant Cell Environment,* **15**, 99-106.

Giovannin, G., Lucchesi, S. and Giacheeti, M., 1990, "Effect of heating on some chemical-parameters related to soil fertility and plant growth", *Soil Science,* **149**, 344-350.

Hussain, A. and Maqsood, M. A., 2011, "Root zone temperature influences nutrient accumulation and use in maize", *Pakistan Journal of Botany*, **43**, 1551-1556.

IPCC, 2007, "Summary for policymakers. In Climate Change 2007 : The Physical Science Basis (eds Solomon, S. D. *et al.*)", Cambridge University Press, Cambridge, UK.

Jackson, M. L., 1973, "Soil Chemical Analysis", Prentice Hall of India Pvt. Ltd., New Delhi.

Karmakar, R., Das, I., Dutta, D. and Rakshit, A., 2016, "Potential effects of climate change on soil properties: A review", *Science International*, **4**, 51-73.

Klein, D. A., Loh, T. C. and Goulding, R. L., 1971, "A rapid procedure to evaluate dehydrogenase activity of soils low in organic matter", *Soil Biology and Biochemistry*, **3**, 385-387.

Liu, L. and Basso, B., 2020, "Impacts of climate variability and adaptation strategies on crop yields and soil organic carbon in the US Midwest", *PLoS ONE* **15**. https://doi.org/10.1371/journal.pone.0225433.

Nannipieri, P., Giagnoni, L., Renella, G., Puglisi, E., Ceccanti, B., Masciandaro, G., Fornasier, F., Moscatelli, M. C. and Marinari, S., 2012, "Soil enzymology : classical and molecular approaches", *Biology and Fertility of Soil*, **48**, 743-762.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A., 1954, "Estimation of available phosphorus in soils by extraction with sodium bicarbonate", USDA Circular 939.

Patel, L. B., Verma, V. K., Toor, G. S. and Sharma, P. K., 2000, "Beneficial plant nutrient supply from ground waters of arid tract of Punjab", *Ecology, Environment and Conservation,* **6**, 105-108.

Patil, A. and Lamnganbi M., 2018, "Impact of climate change on soil health: A review", *International Journal of Chemical Studies*, **6,** 2399-2404.

Tabatabai, M. A. and Bremner, J. M., 1969, "Use of p-nitrophenol phosphate for assay of soil phosphatase activity", *Soil Biology and Biochemistry*, **1**, 301-307.

Verma, V. K., Patel, L. B., Toor, G. S. and Sharma, P. K., 2005, "Spatial distribution of macronutrients in soils of arid tract of Punjab, India", *International Journal of Agriculture and Biology*, **7**, 295-297.

Walkley, A. and Black, I. A., 1934, "An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chronic acid titration method", *Soil Science*, **37**, 29-38.

Wallenstein, M. D., Allison, S. D., Ernakovich, J., Steinweg, J. M. and Sinsabaugh, R., 2011, "Controls on the temperature sensitivity of soil enzymes: a key driver of in situ enzyme activity rates", In: Shukla, G. and Varma, A. (eds.), *Soil Enzymology, Soil Biology*, **22**, Springer-Verlag Berlin, 245-258.

Xu, Q. and Huang, B., 2006, "Seasonal changes in root metabolic activity and nitrogen uptake for two cultivars of creeping bentgrass", Horticultural Science**, 41**, 822-826.

Yadav, B. K. and Gupta N., 2019, "Seasonal variation in soil temperature, physico-chemical properties and micronutrient availability in soils of Pear (*Pyrus communis* L.) orchard under semi-arid environment, *Journal of Agricultural Physics*, **19**, 226-238.

Yadav, B. K., Gupta, N. and Kumar, D., 2018, "Soil micro-nutrient availability and accumulation in ber (*ziziphus mauritiana* l.) under semiarid region" *Multilogic in Science*, **7**, 93-96.

Yadav, B. K., Sidhu, A. S. and Thaman, S., 2016, "Soil fertility status of Punjab Agricultural University seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda, Punjab", *Annals of Plant and Soil Research*, **18**, 226-231.