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

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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. Giovannini 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.
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 \textit{(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 \textit{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) p-nitrophenol 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 (p-NP) at 37 °C, the produced yellow colour intensity was measured colorimetrically at 440 nm. The organic carbon was determined by wet
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).
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 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.
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 to 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 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).
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 compared 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.

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