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A REVIEW OF SOIL TEMPERATURE UNDER A CONTROLLED IRRIGATION SYSTEM

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ABSTRACT
Temperature is the major driver of the climate change whose effects have taken toll on many sectors including agriculture and non agriculture industries. Different temperature ranges are required for various crops, and the least range of soil temperature at which germination takes place without delay is called minimum soil temperature. The term "Soil temperature" is defined as the measurement of the warmth in the soil, which is one of the most important factors affecting plant growth. The optimum range of soil temperature for plant growth is between 20 and 30°C and the rate of plant growth declines drastically when temperature is less than 20°C (sub optimal) and above 35°C (supra optimal). Therefore, all soil processes are temperature dependent. Consequently, the thermal regime of soil strongly influences the edaphic environment which plays a major role in ensuring crop productivity, sustainability and control of biological and biochemical processes that affects soil organic matter formation; fertilizer efficiency; seed germination; plant development and turgidity, nutrient uptake and decomposition; and disease and insect occurrence. Soil temperature is a cogent factor to be considered for effective irrigation scheduling. Concept of global temperature and its impacts on ecosystem were examined. The relationship between soil temperatures with evapotranspiration, soil infiltration and soil moisture were discussed. This study extended to the effects of soil temperature on physical, chemical and biological properties of soil. Factors affecting soil temperature and methods of soil temperature management were highlighted.

Key words: Global Temperature, Soil Temperature, Soil Properties, Temperature, Soil Process, Soil Management

INTRODUCTION

Over the years, supply of water to plants was based on the status of soil moisture content with little or no attention given to soil temperature. In order to achieve optimum irrigation scheduling, considerations are in most cases given to soil water status, crop water stress, crop water requirements and other factors in order to achieve optimum irrigation scheduling without considering soil temperature (Frana, *et al., 2005;* Leifeld, *et al., 2007 and* Curiel, *et al.*, 2004). Positive trend in global temperature should be a major reason why attention must be shifted to soil temperature in achieving productivity through irrigation. Temperature is the major driver of the climate change whose effects have taken toll on many sectors including agriculture and industry. It has been established that different maximum and minimum temperatures are required for different crops, and the least range of soil temperature at which germination will take place without any delay is called minimum soil temperature. Soil temperature plays a major role in ensuring crop productivity, sustainability and control of biological and biochemical processes which invariably affects soil organic matter formation, fertilizer efficiency, seed germination, plant development, ability of plant to survive during dry season, nutrient uptake and decomposition, and disease and insect occurrence (Adak *et al.*, 2011 & 2012; Agren *et al*., 2002; Jacobs *et al*., 2007; Leifeld and Fuhrer., 2005).

Inadequate soil temperature delays crops germination, leads to retarded maturity and undergoes spatiotemporal changes during crop growing season (Adak *et al.*, 2012; Mucaj, 2005). Soil temperature also affects the rate of decomposition of soil organic matter as it is critical in maintaining global carbon and nitrogen balance (Himangshu *et al*., 2016). In view of the recent positive trend in global temperature, soil temperature should be a factor irrigators must look out for when considering irrigation scheduling. The term "Irrigation control system: is a device used to operate automatic watering systems such as drip irrigation systems or lawn sprinklers. It is used to ensure that a desired level of moisture is maintained for the plants with or without the presence of a human operator. In spite of the concerted efforts of governmental agencies, individuals, International organizations and various other bodies to tackle climate change headlong, yet its adverse effects still take toll on every sector which includes agriculture and non-agriculture sectors.

Global Temperature

It is a well known fact that global surface temperature has been on the increase in the last century. Inter Governmental Panel on Climate Change (2007 a, b) reported that temperatures have on the average warmed the land and ocean surfaces in last century at 1.33 ^{o} F (0.74 ^{o} C). This assertion was also supported by All*i*, *et al*. (2019), and Crowley (2000) that over the last 100 years, the global average surface temperature has increased by 0.6 ± 0.2 ^{o}C. Global and regional climate change have been practically influenced by variations in air temperature and these variations are constructed by using different methods based on various assumptions as suggested by the following authors; Briffa and Osborn, 2002; Von Storch *et al*., 2004; Moberg *et a*l., 2005. Amongst the assumptions in which construction of surface air temperature are based are; geothermal influxes are insignificant; variations in terrestrial temperatures are material and central to the construction; and geothermal influxes have little or no effects on terrestrial temperature (Beltrami, 2002).Temperature affects chemical and biological processes such as ecosystem respiration, microbial decomposition of organic matter and oxidation and re- oxidation reactions (Davidson and Janssens, 2006). Temperature plays a vital role in controlling nutrients cycle in terrestrial ecosystems above and below the ground levels (Canadell *et al*., 2007; Zhou *et al*., 2009).

climate change and carbon contents on soil ecosystems

Alli *et al*., (2012) reported that rainfall and temperature trends had significant impacts on climate change just as trends of carbon and carbon dioxide dictate the ecosystem. It has been reported that the quantity of carbon present in the soil is two-third more than the carbon contained in the terrestrial ecosystem (Schlesinger and Andrews, 2000; Hibbard *et a*l. 2005; Davidson and Janssens, 2006). The sequence is that soil ecosystem contains more carbons that terrestrial ecosystem, and terrestrial ecosystem in turn stores more carbon than the atmosphere (Schmidt, 2004). The exchange of carbon dioxide (CO_2) between soil and atmosphere constitutes the major component of the global carbon cycle (Briffa *et al*., 2000). Meanwhile, ability to retain carbon in the soil without leaching depends on factors such as climate, soil parent materials, soil texture; topography, types of vegetation, and soil composition resulting from the activity of microbial decomposing agents (Classen *et al*. 2015). The microbial decomposing agent's activity is already altered by warming and temperature increase, advancing fungal decomposition which invariably facilitates emission of CO_2 efflux from the soil (Peterson *et al*., 1998). Plants are stimulated as a result of the increase in the level of absorption of carbon dioxide which will lead to emission of nitrous oxide and methane (Center for Ecosystem Science and Society, 2011), and excess carbon produced by microbes will fail to be converted into biomass (Zimmer, 2010). Microbial activities in the soil are influenced by nitrogen, and the nitrogen levels present in the soil depend on temperature, higher temperatures increase soil nitrogen level (American Society for Microbiology, 2008).

Effects of global warming on soil temperature

Global warming and climate change are twain phenomena that have direct effects on soil temperature. Global warming increases the microbial activities in the soil which in turn accelerates soil respiration and biomass production (Anderson and Domsch, 2010; Wu *et al.* 2011; Balser *et al*. 2006). Besides, changes in soil respiration as a result of temperature change also influences carbon demands , both quality and quantity of plants biomass production (Eliasson *et al*. 2005; Davidson and Janssens 2006 ; Fierer *et al*. 2005; Rustad *et al*., 2001). Terrestrial temperatures are generated from the terrestrial ecosystem, while surface air temperature is remains the primary source of the variations of the terrestrial temperature (González-Rouco *et al*., 2003). However, increase in surface air and terrestrial temperatures will lead to increase in soil temperature (Qi Hu, 2005)

Soil temperatures

Soil temperature is simply the measurement of the warmth in the soil. Soil temperature is one of the most important factors affecting plant growth. The optimum range of soil temperature for plant growth is between 20 and 30°C (Agren *et al*., 2002, Frey *et al.*, 2013). The rate of plant growth declines drastically when temperature is less than 20°C (suboptimal) and above 35°C (supraoptimal). Further, all soil processes are temperature dependent. Consequently, the thermal regime of soil strongly influences the edaphic environment (Jacobs *et al*., 2007). The release of soil nutrients for root uptake is also dependent upon soil temperature regime. It is a physical parameter that plays a major role in ensuring crop productivity and sustainability (Adak *et al*., 2012 b, Agren *et al*., 2002). It controls biological and biochemical processes in the soil which invariably affects soil organic matter formation, fertilizer efficiency, seed germination, plant development, ability of plant to survive during dry season, nutrient uptake and decomposition, and disease and insect occurrence (Jacobs *et al*., 2007; Leifeld and Fuhrer, 2005). It is also affects the rate of water flow in the soil by controlling water viscosity, surface tension, and relative hydraulic conductivity (Schmidt *et al*., 2004). It controls the rate of decomposition of soil organic matter which is the critical factor in maintaining global carbon and nitrogen balance (Himangshu *et al., 2016*). Inadequate soil temperature delays crops germination, leads to retarded maturity and undergoes spatiotemporal changes during crop growing season (Mucaj, 2005). The ranges of soil temperature for different crops in terms of crop variety selection and farm management practices are presented in Table 1. Accurate or precision in measurement of soil temperature is vital in planning and decision making concerning soil conditions and suitability of crops. Soil temperature continuously varies in response to the changing meteorological regimes acting upon the soil atmosphere interface. The meteorological regimes are characterized by periodic succession of days and nights and rain season and dry season.

Table 1: Temperatures (Farenheit) Range for Selected Vegetables

Vegetable	Will Germinate at	Ideal Germination at	Transplant Seeds at
Beans	60 F	90 F	80 F
Carrot	40 F	90 F	80 F
Corn	50- 100 F	80 F	60 F
Cucumber	60 - 100 F	90 F	65 F
lettuce	40 F	75 F	75 F
Okra	60- 100 F	90 F	70 F
Onion	51- 100 F	80 F	60 F
pepper	60 -90 F	80 F	65 F
pumpkin	60 - 100 F	90 F	65 F
Tom ato	50 - 100 F	80 F	60 F
watermelon	61- 110 F	90 F	65 F

Source: www.gardenersnet.com/gardening/seed-germination-soil-temperature.htm

Minimum soil temperature for crop germination

The least range of soil temperature at which germination will take place without any delay is called minimum soil temperature. Adak *et al.*, (2012) reported that the optimum soil temperature for planting corn is 55 ^{0} F and once the soil temperature attained or above 55 ^{0} F for 5 to 7 days, corn will germinate more quickly. The minimum soil temperatures for crop germination for both agronomic and horticultural crops are presented in Table 2.

Table 2: Minimum Soil Temperature for Crop Germination

Agronomic Crops	Minimum Soil Temp. for planting ^{o}F	Horticultural Crops	Minimum Soil Temp. For planting ^{0} F
Spring wheat	37^{0}	Spinach	38^{o}
Spring barley	40^{0}	Radish	40^{o}
Rye	41^{o}	Lettuce	41^{o}
Oats	43^{o}	Onion	42^{o}
Alfafa	45^{o}	Pea	42^{o}
Spring canon	50^{o}	Potato	45^{0}
Sugar beet	50^{o}	Cabbage	45^{o}
Field corn	55^{o}	Carrot	46^{o}
Soya beans	59^{o}	Sweet corn	55^{o}
Sunflower	60^{o}	Pepper	57^{o}
Millet	60^{o}	Snap beans	57^{o}
Sorghum	65^{o}	Tomato	57^{o}
Dry beans	70^{o}	Cucumber	58^{o}
		Pumpkin	60^{o}

Source: www.gardenersnet.com/gardening/seed-germination-soil-temperature.htm

Relationship between evapotranspiration and soil temperature

The combined effect of evaporation and transpiration is called evapo-transpiration. Transpiration is the escape of water from the soil surface through the stomata of leaves into the atmosphere and evaporation is the direct escape of water in vapor like from the water bodies, soil surface, streams etc into the atmosphere. NASA (2005) reported that up to 400,000 gallons of water in one growing season can be lost into the atmosphere through evapotranspiration. Evapotranspiration is a critical factor in the management of irrigation project with its direct influence on the soil temperature. Evapotranspiration affects soil temperature in such a way that an increase in evapotranspiration will lead to increase in soil temperature and the reverse is the case. The following environmental factors viz relative humidity, temperature, soil water; light, wind etc enhance evapotranspiration in no small measure.

Relationship between soil infiltration and soil temperature

Soil infiltration is simply referred to as the movement of water into the soil. In most cases, infiltration water will end up adding up to the ground water body (Oguntunde *et al*., 2006). The rate at which the infiltration water joins the ground water body is known as infiltration rate. There are certain things that are constant with the infiltration rate which is low or high. If the infiltration rate is low, there will be flooding, water logging, temporary storage of water and depression or ponding which will make soil moisture adequate for crop production. In other hand, if the infiltration rate is high or very high, it will lead to leaching of nitrate nitrogen or pesticides and loss of phosphorus (USDA Soil Health-Guides for Educators 2014). Flooding as a result of low infiltration rate will lead to low soil temperature and high infiltration rate will enhance soil temperature to be fair to crop production.

Relationship between soil moisture and soil temperature

To have better understanding of the interactions between land surface and atmosphere, there will be need for adequate knowledge of the estimation of soil moisture and surface temperature.

Venkat *et al* (2003) reported that an increase in surface temperature will lead to a decrease in the soil moisture which will invariably increase the soil temperature. Soil moisture plays a significant role in the water and energy cycle as it determines the portions of rainwater that goes into runoff, infiltration, depression and surface storage etc. If the relationship between soil moisture and surface temperature is well studied, it will enable researchers in estimating and predicting evapotranspiration.

Effects of soil temperature on some soil properties

Brownmang Onwuka *et al* (2018) reported that soil temperature is majorly affected by environmental factors such as heat. The amount of heat supplied to the soil surface and the amount of heat dissipated from the soil surface down the soil profile has influence on the biophysical properties of the soil. It is confirmed that soil remains the main receiver of the atmospheric temperature and hence soil stores heat during the day and release same to the atmosphere during the night (Grietal *et al*., 2003). Moderate soil temperature influences activities of some enzymes in the soil in such a way that if the soil temperature is increased the microbial activities will be enhanced, soil nitrogen mineralization will be increased hence crop production performs better (Conant *et al*., 2008; Allison *et al*., 2010; Wallenstein *et al*., 2010). In other way round, low soil temperature will lead to decrease in mineralization of nitrogen and the microbial activities will be low; organic decomposition will be enhanced (Grietal *et al*., 2003). Soil temperature also influences soil aeration, soil moisture content and aggregate stability.

Effects of soil temperature on soil biological properties

Some of the biological properties of soil include bio activity, soil micro-organism, soil macro organism, and organic matter decomposition. Soil bio activities are affected by different ranges of soil temperature in diverse ways such as to increase soil respiration. At a soil temperature range of 10 ^{o}C- 28 ^{o}C, the activity of enzymes that degrade polymeric organic matter in the soil will be accelerated which increases soil respiration (Conant *et al*., 2008). Also the microbial intake of soluble substrates, microbial respiration and soil nitrogen mineralization rates will increase at such soil temperature range (Allison *et al*., 2010; Wallenstein *et al*. 2010; Yan L., 2014). Meanwhile, soil temperature below freezing point will slow down microbial activity, diffusion of soluble substrates and lead to decrease in soil mineralization (Kaiser *et al*. 2007).

Soil macro organisms experience increased rate of metabolism which enable them to burn fat at soil temperature range of 10 ℃- 24 ℃ (Conant *et al*., 2008). Most soil micro-organisms thrive well at soil temperature range between 10 ^{o} C and 35.6 ^{o} C, experience positive trends in microbial activities (Davidson and Janssens 2006; Allison., 2005), and meanwhile, at a temperature below 0 ℃, there is slow rate of decomposition (Allison *et al.*, 2010). Organic matter decomposes slowly at lower temperature as a result of decrease in microbial activities and biochemical processes (Gilichirsky, 2011). Soil temperature increases the organic matter decomposition at the temperature range between 2 ℃ and 38℃ (Broadbent, 2015).

Effects of soil temperature on chemical properties of soil

Chemical properties of soil include cation exchange capacity (CEC), phosphorus levels, soil PH level, alkalinity and salinity. Salinity is the presence of salt in the soil as results of contamination from sea water, or salt deposit from the irrigation water after leaching. The availability of salt can be regarded as impurities. Increase in soil temperature decreases organic matter (Ubeda *et al*., 2009) while increase in soil temperature leads to a decrease in the cation exchange capacity of the soil (Rengasamy *et al*., 2009).

Increase in soil temperature from ranges of 25 ^{o}C and 39 ^{o}C will lead to increase soil PH level (Menzies *et al*., 2003). At increase soil temperature of 5 ^{o}C- 25 ^{0}C, phosphorous level of the soil also increase (Yilvainio *et al*., 2012) while soils with low temperature have low availability of phosphate (Gahoonia *et al*., 2003).

Effects of soil temperature on physical properties of soil

Physical properties like soil structure, aggregate stability, soil moisture content, and soil aeration are also affected by soil temperature. Aeration is the presence of air in the soil. Increase in soil temperature causes dehydration of clay and beak down of sandy soils which leads to pulverization and formation of sand-sized and silt- sized particles (Arocena *et al*., 2003 Pardini *et al*., 2004).

Increase in soil temperature at above 30 ^{o} C leads to soil aggregate stability which in most cases enhance gumming or cementing ability of the clay soil due to the thermal transformation of iron and aluminum oxide (Fox *et al*., 2007; Terefe *et al*., 2008). Increase in soil temperature leads to decrease in soil moisture content and increase in soil aeration (Broadbent, 2015; Allison, 2005).

Effects of soil temperature on plant growth

Increase in soil temperature leads to increase water intake, nutrient up take, improve root growth and flowering and yields increase (Toselli *et al*., 1999; Weih *et al*., 1999). Soil temperature alters soil water viscosity and nutrient transport at the root zone which invariably affects nutrients uptake of the plants (Grossnickle., 2000; Lahti *et al*., 2002).

Factors Affecting Soil Temperature and Management of Soil Temperature

Factors affecting soil temperature

Higher precipitation will lead to lower soil temperature. Precipitation will increase the soil moisture content which will invariably lead to decrease in soil temperature (Lin *et al.*, 2003; Bartlett *et al.*, 2004). Precipitation and surface air temperature relationship influence soil temperature in such a way that if surface air temperature is increased the soil temperature will be increased and the increase in surface temperature will increase the rate of evaporation and transpiration which invariably reduces soil moisture content (Bartlet*t et al.*, 2004). Soil temperature depends on the nature of surface which is affected by vegetation. The vegetation alters the soil energy balance in a number of ways,which include; (i) altering albedo, (ii) insulating soil surface to prevent heat exchange, (iii) reducing depth. of penetration of solar radiation, and (iv) increasing the removal of latent heat by evapotranspiration (Jury *et al*., 2009).

Management of soil temperature

Soil temperature can be managed in a number of ways, which includes mulching, tillage, irrigation, drainage, cover crop or shading, and application of dark or light powder/ material (Scott, 2000) The management options depend whether the temperature of soil needs to be increased or reduced. Scott (2000) and Jury *et al*. (2009) highlighted the soil temperature management methods as follows:

(i) Ridge tillage increases surface soil temperature by increasing the area exposed to radiation and decreasing soil moisture.
(ii) The maximum and minimum temperatures at the surface of a plow-till soil are also much higher than a no-till soil. Similar to no-till, mulching with crop residue decreases the maximum soil temperature and increases the minimum soil temperature.
(iii) Irrigation with cold water during the summer results in bringing down the temperature of surface soil. Similarly, drainage has a strong influence on soil temperature. Therefore, removal of excess water by surface or subsurface drainage increases soil aeration, which in turn warms the soil surface.
(iv) Building large mounds in a poorly drained (hydromorphic soil) increases soil temperature

CONCLUSION

Proper management of soil temperature under a controlled irrigation system is imperative for healthy plants growth, environment and biomes. Soil temperature also dictates the rate of infiltration in the soil in which water viscosity, surface tension, and relative hydraulic conductivity are controlled for plants growth. Soil temperature affects the rate of decomposition of soil organic matter as it is critical in maintaining global carbon and nitrogen balance. Soil temperature can be managed in number of ways which includes mulching, tillage, irrigation, drainage, cover crop or shading, and application of dark or light powder. However, accurate or precision in measurement of soil temperature is vital in planning and decision making concerning soil conditions and suitability of crops

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