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The Impact of Soil Temperature on Miscanthus (Elephant) Plant: A Case study of Compton Experimental Site, West Midlands, UK

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Abstract: ***The study explored the response of Miscanthus (elephant) plant to soil temperature at Compton, based on the statistical analysis of the database of (12,045) days of individual soil temperature measurement in sandy-loam of the salwick series soils. Soil temperature at Compton research site significantly increased between 1975-2008 at a rate of ~0.1^{0}C year $^{-1}$. However, the rate of increase in the mean annual soil temperature notably affect the growth and survival of Miscanthus (elephant) plant, this was due to the fact that the plant display structural dormancy behavior which is generally attributed to warming effect. Warming was found to exert a very severe problem to the plant. Similarly, it was found that the reaction of this plant to increase in soil temperature was clearly detected. It has been observed that changes of significant proportion in the morphology of the plant was evident. The changes include in active appearance and stunted growth during the early stage of it development while withering, yellowing discolouration and falling of leaves was apparent during the maturity stage. The study concludes that all these changes appeared to be essentially associated with increase in soil temperature.***

Keywords: Soil temperature; Miscanthus; Agriculture; Plant growth

1. Introduction

Soil temperature are the key environmental factor that enhance the growth of many plant, in the light of this, understanding of the soil temperature trend can assist to a very large extent in determining the type of crops to be grown in a given soil temperature conditions. Attention in this area of study is always increasing and thus, soil temperature has been the focused of studies among scholars, including Hu and Feng (2003), Subedi and Fullen (2009), Kohn and Royer (2010), Bai *et al.* (2010), Zavala *et al.* (2010), Tang *et al.* (2011), Brown and Degaetano (2011), Rinnan *et al.* (2011), Ikeda (2002), Martinez *et al.* (2008), Qian *et al.* (2011), Adrie *et al.* (2011), Uvarov *et al.* (2011), Kang *et al.* (2000), Cookson *et al.* (2002), Zhang *et al*. (2008), Cassagne *et al.* (2008), Zhang *et al*. (2005) and Kovacs *et al*. (2011),with emerging views that soil temperature contribute significantly to the growth and survival of many crops.

The role of soil temperature in plant growth was studied by Ghahreman *et al.* (2010), Ikeda (2002) and Martinez *et al.* (2008). They reported that soil temperature plays a very important role in the growth and development of crops, regulates the rate of seed germination and influences the growth and development of roots. Similar findings were found by Hu and Feng (2003), who argued that several crops (such as oats, beans, maize and wheat) are significantly influenced by soil temperature anomalies at different depths.

Adrie *et. al.* (2011) argued that soil temperature direct certain processes in the soil including biochemical and biological activities which, later impinge on seed germination, organic matter formation, continue existence of plant during winter and diseases as well as incidence of insect, fertilizer effectiveness and plant growth. Many ecosystem processes such as seed germination, active soil organism, the growth of plant root, nutrient uptake and break down are all influence by soil temperature anomalies. Also, soil temperature activities plays a vital role in farm management practice and crop variety selection.

Subedi and Fullen (2009) observed that soil temperatures has an enormous importance for the development and thus efficiency of agricultural crops and woodland plantations. Furthermore, soil temperature affects soil hydrology, plant diseases and over-wintering of pathogens (Marshall and Holmes 1979; Philips *et al* 1999; Pivonia *et al*. 2002, cited in Subedi and Fullen 2009). In terms of decision-making for farming and selecting management alternatives, information on soil temperature is vital. Overall, development and growth of many crops and plants that grow yearly stop at temperatures <6-10^{0}C. Therefore, temperature lower than this range will hinder the growth and survival of many crops.

Chang *et al.* (2011) demonstrated that in humid agricultural lands, soil temperature and surface soils are significantly influenced by periodic air temperature variation during the summer season (Margesi *et al.* 2001; Poland *et al*. 2007, cited in Chang *et al.* 2011).

Sierra *et al.* (2010) argued that in the tropics, climate warming may influence soil organic matter content and soil fertility status through its direct effect on the rate of microbial processes. This has indirect consequences for crop development, carbon input from crop remains and soil carbon mineralization.

Xu *et al.* (2004) noted that soil temperature periodic frosts, low light and soil temperature limit the development of crops during the cold season. Similarly, in spring, warming temperatures, length of day and sufficient soil moisture accelerated grass development.

Kang *et al.* (2000) noted that soil temperature is reliant on several variables, together with meteorological variables such as air temperature, surface global heat and soil physical parameters. Soil parameters include water content and texture with landscape variables (such as slope, aspect and elevation). Furthermore, Mellander *et al.* (2004) studied the influence of soil temperature on transpiration, and found that soil temperature does not singularly establish the commencement of transpiration separately from other factors. Bergh *et al;* (1999) (cited in Mellander *et al.* 2004) suggested that it is a joint influence of soil temperature and the effect of ground conditions, such as air temperature, length of day and time scale after winter.

Many scholars analyzed the response of Miscanthus under different temperature environmental conditions. Three important studies for example, were that of Farrel *et. al.* (2006), Hasting *et. al.* (2008) and Roth *et. al.* (2013) their contribution show a great extent of interest and knowledge in this field of study.

It is therefore, essential to examine soil temperature behavior with a view to unearth the distinctive attribute of this particular soil thermal environment and apply this knowledge, to Miscanthus (elephant) plant.

The impact of soil temperature on Miscanthus (elephant) plant has not been explored in the study area. Therefore, this study is considered desirable. The aim of the study is to examine the impacts of soil temperature on Miscanthus (elephant) plant that grows within the study area. However, this investigation contributes to bridge this gap and contribute immensely to the knowledge on secular trends.

2. The Study Area

Since 1970, The university of Wolverhampton established a meteorological station situated in Compton Campus, West Midlands (UK), is used for studies on plant experiment, soil conservation, and meteorology within 2.39km. The research site is located at 52.58717O and 2.1634830, (URL: itouch map), the meteorological station at the upper flat section has undersize grass cover and Miscanthus (elephant) plant as part of long term meteorological observation.

Brandsma (1997) reported that the nature of the soil at the research site is predominantly sandy-loam of the Salwick series with a dark topsoil of 32 cm deep and a sandstone rock underneath. Similarly, the texture of the soil consists of sandy silt loam 41.4% (2000-60 µm), silt 51.3% (60-2 µm), clay 7.3% (< 2 µm) and soil organic matter content is 2.7% by weight. The pH level is 6.5 (Vaz, 2001).

Figure 1: Rain gauge, 60 cm thermometer, slab minimum thermometer, short grass and Miscanthus (elephant) plant at the extreme side of the study area.

3. Materials and Method

Meteorological parameters at Compton was determined using a 60 cm deep thermometer, slab minimum thermometer, rain gauge, bare earth minimum thermometer and an anemometer, a Stephenson's Screen (maximum and minimum wet and dry bulb) which is used to measure air temperature and relative humidity. The soil thermometer were installed at four depths of 5, 10, 20 and 30 cm. Readings were taken twice in a day (morning and evening) since 1975.

Data for the present study on soil temperature was collected at Compton research Site. These soil temperature data were measured at different soil depths based on thirty seven years of observation 1975-2012. This study analyses the soil temperature data recorded between1975-2008. Results are analyzed using statistical methods (Excel package). The statistical analysis involves descriptive statistics (mean, median, minimum and maximum temperature). Correlation and regression analysis were used to identify temporal trends in soil temperature.

General features

There are total of 698 pages of Excel data, 13,860 lines of Excel data and a total of 12,045 days of soil temperatures measurement at Compton, which the study analyzed.

4. Results and Discussion

Compton is specifically a research site for studies on soil temperature, plant experiment and soil conservation. Hence, the materials, observations and measurements from this area are habitually treated as reference point for the aforementioned analysis and other important environmental modifications.

Soil temperature measurement at Compton research site commenced in 1975, from then onward the experimental site has a history of 39 years (1975-2014) with usual records of soil temperature at four depths 5, 10, 20 and 30 cm. Therefore, the data offered a suitable plat form to examine soil thermal behavior and it is fascinating and also essential to appraise the impact of a significant increase in soil temperature on Miscanthus as this will play a very significant role in various areas. It has been observed that soil temperature is very important for the development of many plants.

The results show that soil temperature at Compton significantly increased at rate of ~0.1^{0}C year $^{-1}$. The rate of increased was found to affect the plant to a very large extent.

$$y = -74.28 + 19.10 x$$

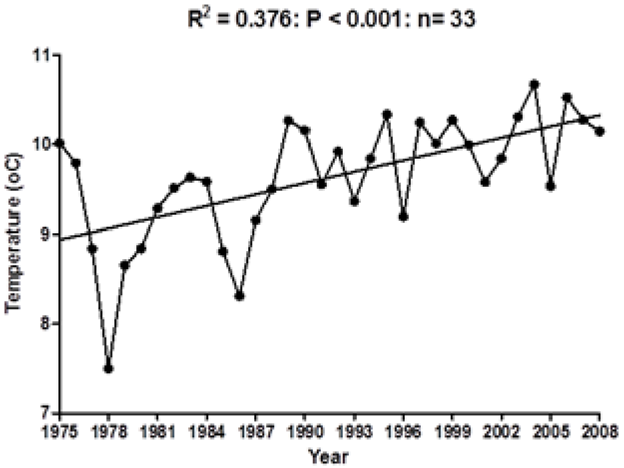

Figure 2: Mean annual soil temperature (mean of 5, 10, 20 and 30 cm depths) during the years 1975-2008 at the Compton Experimental Site.

A trend of mean annual soil temperature variation was observed during this period. The mean annual temperature (mean of all depths) decreased from 10^{0}C in 1975-1978 due to cold winter and snowfall and thereafter, temperature continuously fluctuated. This follow a linear trend ($r = 0.548$; $p < 0.001$; $n = 33$) (where n = means of individual years). This trend revealed a significant increase in soil temperature between 1975-2008 at a rate of ~0.1^{0}C year $^{-1}$. The regression statistics trend reveals that there was a significant increase in soil temperature during this period.

These increased in soil temperature affect the growth and survival of Miscanthus (elephant) plant as changes of significant proportion was clearly detected. This plant grows within the study area and is adversely affected by the mean soil temperature increase. During the period of this study, it has been observed that the original morphology or structure of the plant has been greatly distorted. This is quite different from the original structure of the plant, indicating the occurrence of a problem.

Pregistzer *et al*. (2000) observed that soil temperature can influence root growth (e.g. the commencement and termination of growth, extent of root and diameter extension, cell elongation, beginning of new lateral roots and root branching patterns). Warmer soil temperature often result in increased root respiration and ion uptake, if other factors, such as drought and light do not limit the structural action of plants. Subke and Bahn (2010) argued that an obvious thermal acclimation is usually caused by the reduction of substrate pools within soils, rather than natural ability of the soil to adapt to changes in temperature.

Further assessment of the data base was conducted during 1975-2008 to study the thermal climate of soil and patterns of change. It has been observed that considerable changes have occurred from the early growth of the plant such as inactive appearance and stunted growth, no symptom of water and nutrient shortfall was examined.

Therefore, during the maturity stage of it development withering, yellowing discolouration and falling of leaves was also apparent. Similarly, during the years 2011 and 2012 growing seasons, the behavior of Miscanthus (elephant) plant were carefully monitored, but only a small differences was found in the morphology and a minute portion of the leafs as compared to the development period which was strongly attributed to warming effects.

Ahmad and Rasul (2008) argued that the amount of crop harvested depend greatly on many factors, such as soil. Soil temperature significantly influence maturity rate and plant growth. (e.g. chemical reactions speed up and result in more rapid seed germination due to increased soil temperature). Soil temperature also plays a major role in decomposition processes in soil. It also determines the level of water content in the soil, be it in a gaseous, frozen or liquid form. In soils of cold regions, the frequency of decomposition of organic matter tend to be very slow due to the inability of soil micro-organisms to function effectively.

All the observed changes was essentially linked to increase in mean annual soil temperatures, the warming trend affect the plant to a very large extent. Hoyle *et. al.* (2013) argued that soil warming generally decrease germination from the soil, reaction of germination to soil temperature depend largely on the particular type of plant and thus, overall variety of the plant richness tend to increase with soil warming.

Hu and Feng (2003) observed that data on soil temperature, air temperature and precipitation could be used to assess the viability of growing different crop. It can also be used to describe the influence of soil temperature on agriculture and aid in evolving useful techniques to maintain and increase agricultural production.

5. Conclusion

The results of the study clearly illustrated that soil temperature at the research site significantly increased between 1975-2008 at a rate of ~0.1^{0}C year $^{-1}$. The rate of increased in mean annual soil temperature significantly impinged on the growth and survival of Miscanthus (elephant) plant, this was due to the fact that the plant exhibited structural dormancy behavior which is commonly attributed to warming effect. Warming was found to exert a very serious problem to the plant. Similarly, it was found that the response of this plant to increased in soil temperature was clearly detected. It has been observed that major changes in the morphology of the plant was evident. The changes include in active appearance and stunted growth during the early stage of it development while withering, yellowing discolouration and falling of leaves was apparent during the maturity stage. The study concludes that all these changes appeared to be essentially associated with increase in soil temperature.

In addition, more detail analysis of soil temperature trend and its effect on plants is still in progress at Compton with a view to provide a clear understanding of the sequence of growth in a changing soil temperatures environmental conditions. This will create awareness, interest and knowledge on temporal temperature trends.

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