Scientia Agraria Paranaensis
Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

SOIL TEMPERATURE AND AGRONOMIC IMPLICATIONS IN TWO REGIONS OF THE STATE OF SÃO PAULO, BRAZIL

Maurício Dominguez Nasser[1*], Estefânia Martins Bardiviesso[2], Ariel Santivañez Aguilar[2], Augusto Zonta[3]

SAP 22578 Received: 07/06/2019 Accepted: 14/08/2019
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 1, jan./mar., p. 12-17, 2020

ABSTRACT - Plants can tolerate a wide range of soil temperature variations, but their development is affected when the soil undergoes higher or lower temperatures of certain extreme values. The aim of this study was to assess the soil temperature of two regions of the state of São Paulo, Brazil. Daily measurements of soil temperature were taken at two weather stations, one in the municipality of Adamantina (soil classified as Podzolic, Dark Red Latosol, Eutrophic, moderate A, of sandy/medium texture) and another in the municipality Monte Alegre do Sul (soil classified as Red Yellow Podzolic, of fine sandy-clayey texture) within a period of 365 days. The experimental design was completely randomized, with the two municipalities being the treatments, and 12 repetitions determined by monthly averages. The soil temperature at a 3-cm depth in Adamantina reached values above 40°C, values not observed in Monte Alegre do Sul. At a 12-cm depth, there were no differences between the municipalities. In Monte Alegre do Sul, the recorded soil temperatures proved suitable for crops, with better use of organic matter by the soil and greater stability of surface temperature throughout the day compared to Adamantina. In Adamantina, however, the use of agronomic technology is required to ensure greater stability of surface temperature. The temperature throughout the year in the soil surface layer in the Adamantina region in the afternoon was higher than in the Monte Alegre do Sul region, a fact that implies the need of differentiated agronomic technology depending on the cultivation location.
Keywords: microbial activity; plant development; soil physics; thermal index.

TEMPERATURA DO SOLO E IMPLICAÇÕES AGRONÔMICAS EM DUAS REGIÕES DO ESTADO DE SÃO PAULO

RESUMO - As plantas podem suportar ampla variação de temperatura do solo, mas o desenvolvimento torna-se comprometido a partir do momento em que o solo apresenta temperaturas maiores ou menores de determinados valores extremos. Objetivou-se com esse trabalho avaliar a temperatura do solo em duas regiões do estado de São Paulo. Foram realizadas medições diárias de temperatura do solo em duas estações meteorológicas, sendo uma em Adamantina (solo classificado como Podzólico Vermelho Escuro, latossólico eutrófico A moderado, textura arenosa/média) e outra em Monte Alegre do Sul (solo classificado como Podzólico Vermelho-Amarelo, textura fino-areno-argilosa) durante 365 dias. O delineamento experimental foi inteiramente casualizado, sendo duas cidades os tratamentos, e 12 repetições determinadas pelas médias mensais. A temperatura do solo a 3 cm em Adamantina atingiu valores acima de 40°C, o que não foi verificado em Monte Alegre do Sul. A 12 cm de profundidade não se observou diferenças entre os municípios. Em Monte Alegre do Sul, as temperaturas registradas mostram-se adequadas para o cultivo, tendo maior aproveitamento da matéria orgânica e maior estabilidade de temperatura superficial ao longo do dia em comparação a Adamantina. Para Adamantina, requer-se o emprego de tecnologias para maior estabilidade superficial de temperatura do solo. A temperatura do solo ao longo do ano na camada superficial na região de Adamantina no período da tarde é superior a região de Monte Alegre do Sul, o que infere tecnologia agronômica diferenciada para os tratos culturais em função da região de cultivo.
Palavras-chave: atividade microbiana; desenvolvimento de plantas; física do solo; índice térmico.

INTRODUCTION

Soil temperature is one of the agronomic aspects that interfere in plant development. It can affect water content, absorption and availability of nutrients in soil, root growth, microbial activity, seed germination, rooting of cuttings, and reactions of soil formation (PREVEDELLO, 1996; ABCSEM, 2015; MENESES et al., 2016).

The thermal index of a soil is evaluated according to the soil surface heating under solar radiation and the sensible heat transfer to its interior by means of conduction. Therefore, several factors determine soil

[1]Agronomist, PhD, Scientific Researcher, APTA - São Paulo's Agency for Agribusiness Technology, Alta Paulista Regional Hub, Adamantina, São Paulo, Brazil. E-mail: mdnasser@apta.sp.gov.br. *Corresponding Author.
[2]Agronomist, PhD in Horticulture, State University of São Paulo (UNESP), Botucatu, São Paulo, Brazil. E-mail: estefania.bardiviesso@hotmail.com, ariel_trex89@hotmail.com.
[3]Animal Scientist, MSc, Scientific Researcher, São Paulo's Agency for Agribusiness Technology, Alta Paulista Regional Hub, Adamantina, São Paulo, Brazil. E-mail address: zonta@apta.sp.gov.br.

temperature such as global solar irradiance, air temperature, rain, wind, cloudiness, type of surface cover, relief and type of soil (PEREIRA et al., 2002).

Mota (1983) pointed out that soil temperature exerts greater influence than air temperature regarding the ecological impacts for plants. This type of information is of utmost importance for agriculture professionals (GASPARIN et al., 2005). Plants can tolerate a wide range of soil temperature variation, but their development is significantly affected when the soil undergoes higher or lower temperatures of certain extreme values

High soil temperatures interfere in physiological and biochemical processes by reducing plant growth, thus intervening in stomatal conductance, electron transport, membrane integrity, enzyme action and photophosphorylation (SHOAIB et al., 2012; HILLEL, 2004). Soil temperature variations in the root zone are reported to negatively affect strawberry crops in terms of plant growth, fruit yield and quality (GONZALEZ-FUENTES et al., 2016).

Soil temperature variations are more evident at a depth of up to 10 cm, at which a large part of the roots and microbial activity develop. In this respect, the primary factor that affects microbial activity and soil respiration rates is the soil temperature (KOCH et al., 2007). Between layers, heat transfer is controlled by conduction and convection mechanisms and, due to changes in physical structure, these processes can affect soil in different ways (BONETTI et al., 2017). Given that every geographic region has different characteristics of climate and soil, further studies on soil temperature are necessary, since very few studies have addressed such an important variable, which may imply decisions on different agronomic treatments depending on the cultivation location.

The major agricultural activities in the Adamantina region are the cultures of fruit, vegetables, coffee, achiote, cassava, peanuts, rubber trees, eucalyptus, sugarcane, and pastures. In Monte Alegre do Sul, the predominant cultures are pastures, eucalyptus, coffee, maize, sugarcane, fruit and vegetables.

In view of the above, the present study aimed to assess the soil temperature of the two mentioned regions of the state of São Paulo, Brazil, with the purpose of contributing to the agronomic technology used for crops of larger areas in both regions.

MATERIAL AND METHODS

Daily measurements of soil temperature were taken at two weather stations within a period of 365 days, from March 5, 2014 to March 4, 2015 (Figures 1 and 2), using data provided by the CIIAGRO (Centro Integrado de Informações Agrometeorológicas).

One of the weather stations in this study is the automatic station installed in the municipality of Adamantina, located in the west of the state of São Paulo, at a latitude of 21°40’05,70”, a longitude of 51° 08’40,93” and an altitude of 402 m. The soil of the region was classified as Podzolic, Dark Red Latosol, Eutrophic, moderate A, of sandy/medium texture (PRADO et al., 2003), and the relief was characterized as slightly undulating. During the evaluation period, the mean minimum and maximum air temperatues were 17.94°C and 30.78°C, respectively, with total rainfall of 1072 mm.

The other weather station is installed in the municipality of Monte Alegre do Sul, located in the east of the state of São Paulo, at a latitude of 22°41’35,50”, a longitude of 46°40’23,23” and an altitude of 782 m. The soil of the region was classified as Red-Yellow Podzolic, which today would correspond to alluvial Red Yellow Argisol, unit of Monte Alegre, of fine sandy-clayey texture, and an undulating to strongly undulating relief, according to Rotta et al. (1971). During the evaluation period, the mean minimum and maximum air temperatures were 14.24°C and 28.75°C, respectively, with total rainfall of 1146.2 mm.

The experimental design adopted was completely randomized, with the two municipalities being the treatments, and 12 repetitions. Each repetition was determined by the average of 30 samples of each variable for the 30-day months, and 31 samples for the 31-day months. The variables analyzed were soil temperature at at depths of 3 and 12 cm, at 8:00 a.m. and 2:00 p.m.

The data obtained were submitted to analysis of variance and when there was significance as per the F test, the means of the soil tillage treatments were compared by the Tukey’s test, at a 0.05 significance level. For the statistical analysis, the SISVAR statistical program was used as an aid (FERREIRA, 2010).

RESULTS AND DISCUSSION

As can be seen in Figures 1 and 2, regardless of the region, soil temperature plummets right after a rain. This can be explained by the fact that rainfall interferes significantly in the action of solar radiation on the soil surface, and consequently contributes to the frequent changes in temperature during the year (CARNEIRO et al., 2014). This factor also relates to the soil reflection coefficient, which decreases when the soil surface is moist, even with the thermal conductivity increased by the presence of water, causing the soil temperature to decrease (PREVEDELLO, 2010).

When analyzing the action of humidity over soil temperature, Silva et al. (2006) observed temperature variations occurring in different soil management systems with no-tillage under irrigation conditions; however, those managements did not influence the productivity of the crop (common beans).

Within the period studied for the two regions, the soil temperature at a 3 cm depth in Adamantina frequently reached values above 40°C, a fact that was not observed in Monte Alegre do Sul. This factor would probably imply greater evapotranspiration in the region of Adamantina, meaning that irrigation management would have to be differentiated for a crop implemented under the same conditions as in Monte Alegre do Sul. In addition to irrigation management, elevated temperatures accelerate the process of degradation of soil and organic matter, as according to Hansen et al. (2018), the activity of bioenzymes responsible for degradation increases with temperatures of 30 to 50°C, depending on the type of soil. Thus, there is a greater need to monitor and incorporate organic matter into the soil.

Risser et al. (1978) reported that the effect of soil temperature is greater in the periods of sowing, emergence and initial growth, when significant daily thermal amplitudes occur, mainly in the surface layer. Gasparin et al. (2005) analyzed the temperature in the soil profile in Cascavel, state of Paraná, Brazil, and observed that the greatest variations in soil temperature occurred at a depth of 2 cm. From 8 a.m. onwards, geotemperatures kept rising until they reached a maximum value at around 2 p.m., and from then on they started to decrease. According to Prevedello (2010), soil temperature variations tend to disappear at depths exceeding 40 cm; however, this variation decrease depends on the amount of water in the soil and its degree of compaction, since water, in involving the solid particles of the soil, produces an effective contact area, leading to an increase in the thermal conductivity of the soil.

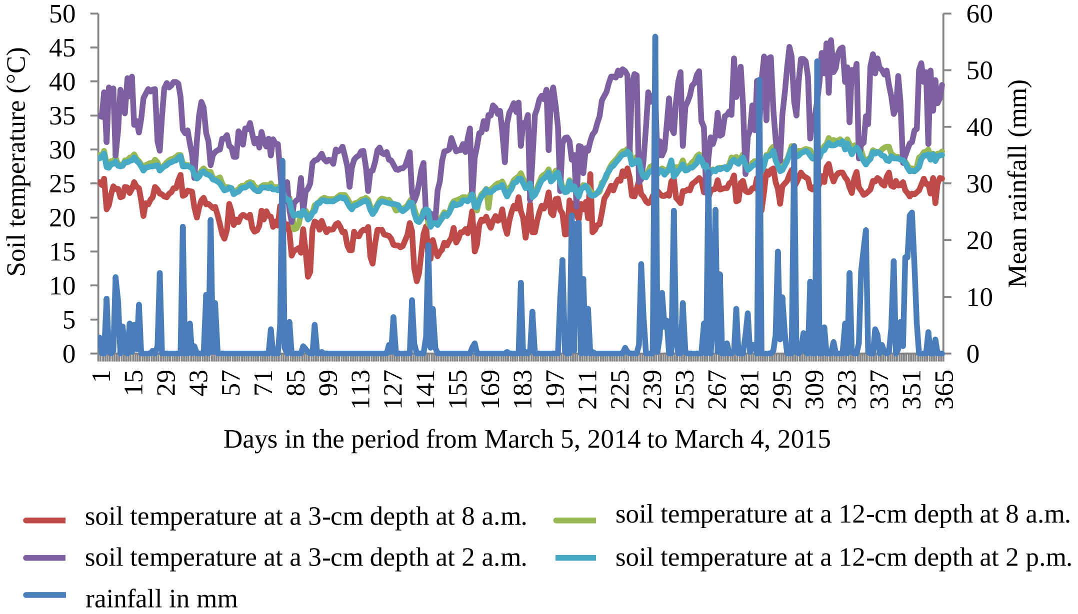

FIGURE 1 - Daily data of soil temperature and rainfall in the period from March 5, 2014 to March 4, 2015 in Adamantina, São Paulo State, Brazil.

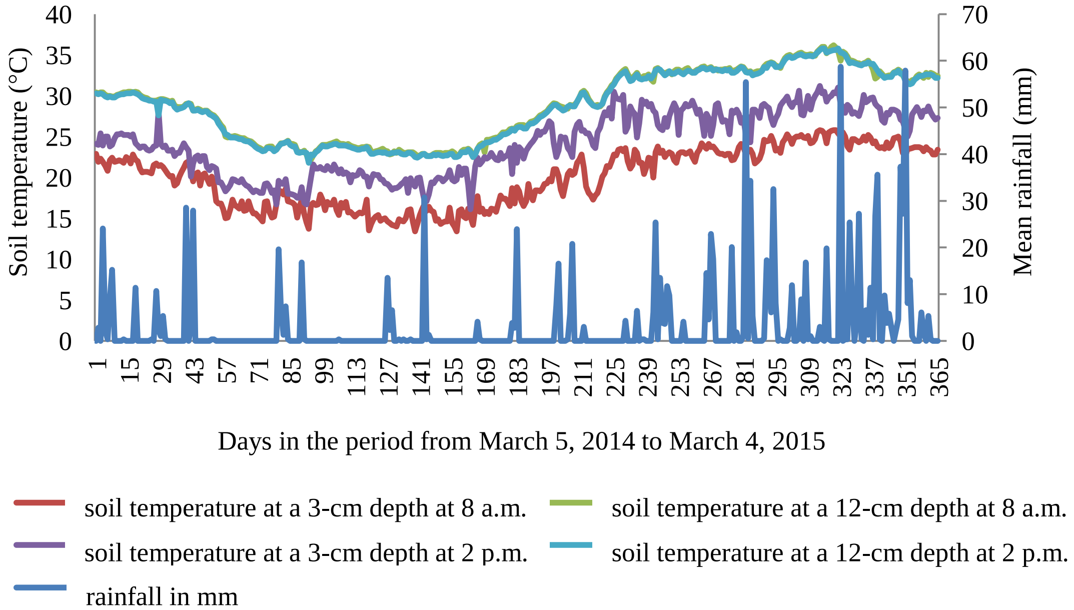

FIGURE 2 - Daily data of soil temperature and rainfall in the period from March 5, 2014 to March 4, 2015 in in Monte Alegre do Sul, São Paulo State, Brazil.

Table 1 shows a significant difference in soil temperature at 2:00 p.m. at a 3-cm depth, with an average of 33.43°C for Adamantina and 24.18°C for Monte Alegre do Sul. At a 12-cm depth, no differences between regions were observed, neither in the morning nor in the afternoon. As can be seen, the soil in Adamantina has low diffusivity, as it has high surface temperatures, with no heat penetration at greater depths as time goes by. According to Silans et al. (2006), soil thermal diffusivity depends on several factors such as granulometry, structure, soil density, among other factors. The comparison between the two types of soil under analysis, based on the relevant classification, indicates that the soil in Adamantina has a sandy characteristic, while that of Monte Alegre do Sul has a greater amount of clay, which explains why the latter presents better heat transfer downward in the soil.

TABLE 1- Soil mean temperature (°C) from March 5, 2014 to March 4, 2015, at different depths and times of the day, in two municipalities in the state of São Paulo, Brazil.

Municipality in São Paulo state	Soil depth (cm)			
	3		12	
	Time of day (h)			
	8:00	14:00	8:00	14:00
Adamantina	21,68 a*	33,43 a	26,13 a	25,78 a
Monte Alegre do Sul	19,97 a	24,18 b	28,87 a	28,73 a
Overall mean	20,82	28,80	27,50	27,26
F	$1,53^{ns}$	32,35 **	$3,22^{ns}$	$3,75^{ns}$
CV(%)	16,30	13,83	13,61	13,66
DMS	2,87	3,37	3,17	3,15

*Means followed by the same lower case letter in the column do not differ by Tukey's test at a 0.05 significance level. CV = coefficient of variation, ^{ns} = not significant at a 0.05 significance level by the F test. **significant at a 0.01 significance level by the F test.

In Adamantina, the predominant cultures are fruit and vegetables in general. Substantial information about top soil temperature on the surface layer may for example imply different management recommendations for those cultures, such as irrigation and methods to avoid excessive soil surface heat, in addition to providing better understanding of the evapotranspiration process and soil water balance.

For strawberry crops, Passos et al. (2014) recommend using ammoniacal and nitric nitrogen when the soil temperature is between 12 to 27°C and using nitrogen in the nitric form when it is above 27°C, since, according to those authors, applying ammoniacal N in high dosages can intoxicate the strawberry roots. Nitrate is one of the forms in which plants absorb nitrogen, especially at high temperatures, but most plants do not absorb it at soil temperatures above 32°C. Soil coverage aims to prevent from heat. Techniques such as mulching, irrigation, afforestation, increased planting density, and intercropping can avoid this risk (PRIMAVESI, 2003).

According to Kiehl (1985), soils with a temperature below 25°C can easily accumulate organic matter, but soils exposed to higher temperatures favor decomposition. This can make agricultural cultivation unsustainable and more dependent on external resources of rural property, since organic matter contributes more than 70% of the cation exchange capacity (RAIJ, 1969), which does benefit soil fertility.

Based on the temperature values obtained, it can be assumed that Monte Alegre do Sul has better use of soil organic matter, which is of paramount importance since the predominant cultures in the region are coffee, eucalyptus and sugarcane – perennial and semi-perennial cultures that require large amounts of nutrients in slow release throughout the cycle.

In the Adamantina region, lower in altitude than Monte Alegre do Sul, the soil temperature reached higher values, which indicates better seed germination rates, for instance in vegetables of the Cucurbitaceae family (pumpkin, cucumber, melon, watermelon , gherkin), and eggplant, green beans, scarlet eggplant, okra, peppers, green maize and even sprouts of sweet potatoes and chayote. In the soil of such cultures, the mean temperature variation ranges between 25°C and 30°C, reaching up to 35°C, as is the case with melons. Onion crops have an intermediate behavior, with 20 to 30°C of soil temperature for germination). For other conventional vegetables such as lettuce, tomatoes, potatoes, kale, cauliflower, broccoli, carrots, chives, beets, radishes, garlic, the optimal range of soil temperature is around 15 to 25°C (ABCSEM , 2015), that is, a temperature typical of regions with a milder climate, such as Monte Alegre do Sul.

Rena and Guimarães (2000) report that, in coffee crops, higher soil temperatures produce lateral roots in a more vertical position, deepening the root system. Under field conditions, it causes significant changes in the occurrence and distribution of roots. According to Serrano Júnior (2002), the optimal range of soil temperature for the organic management of fruit trees ranges from 20 to 32°C, and for this reason the author recommends dead and live cover. This technique contributes to the maintenance of soil moisture, reduces losses owing to evapotranspiration (KOSTERNA et al., 2014), and may be indicated in regions with low or poorly distributed rainfall throughout the year. In terms of vegetation cover, Prevedello (1996) characterizes straw as a material with low thermal conductivity and high reflectivity of sunlight. In addition, straw covering provides organic matter, which is as a source of nutrients for plants and microorganisms, and contributes to the maintenance of the soil water content and decreases geotemperature oscillations (VOOS and SIDIRAS, 1985).

Advantages of soil cover using synthetic or organic materials have also been reported for vegetables such as lettuce (MENESES et al., 2016), garlic (JAMIL et al., 2005), potatoes (KAR; KUMAR, 2007), carrots (RESENDE et al., 2005), melons (JOHNSON et al., 2004), peppers (QUEIROGA et al., 2002), and tomatoes (GRASSBAUGH et al., 2004). Remarkably, associating the soil temperature at a 3-cm depth (Table 1) with the conventional process of plant and animal waste composting, it is in the thermophilic phase (above 45°C in organic waste composting) that maximum decomposition of organic matter occurs, with active degradation of polysaccharides, transforming them into food for the microbiota (PEREIRA NETO, 2007). In this respect, it can be inferred that the Adamantina region may present a faster rate of organic matter decomposition than the Monte Alegre do Sul region, which implies lower values of cation exchange capacity and decreased soil fertility in low-altitude agricultural regions.

In view of the above, this study highlights the need for further research on soil temperature associated with cultures in both annual and perennial crops. In this vein, it is justifiable to evaluate the development and production of plants in different vegetation covers, as well as the influence of irrigation, afforestation, and increased planting density.

CONCLUSIONS

In Monte Alegre do Sul, the recorded temperatures proved suitable for crops, showing better use of organic matter by the soil and greater stability of surface temperature throughout the day compared to Adamantina.

As for Adamantina, it was found that additional agronomic technology is required to obtain greater surface stability of soil temperature.

The temperature throughout the year in the soil surface layer in the Adamantina region in the afternoon was higher than in the Monte Alegre do Sul region, a fact that implies the need of differentiated agronomic technology depending on the cultivation location.

REFERENCES

ABCSEM. ASSOCIAÇÃO BRASILEIRA DO COMÉRCIO DE SEMENTES E MUDAS. **Manual técnico para cultivo de hortaliças.** Campinas: Finco Agrocomunicação, 2015. 100p.

BONETTI, J.A.; ANGHINONI, I.; ZULPO, L. Temperatura e umidade do solo em sistema de integração soja-bovinos de corte com diferentes manejos da altura do pasto. **Revista Scientia Agraria**, v.18, n.2, p.11-21, 2017.

CARNEIRO, R.G.; MOURA, M.A.L.; SILVA, V.P.R.; SILVA JUNIOR, R.S.; ANDRADE, A.M.D.; SANTOS, A.B. Variabilidade da temperatura do solo em função da liteira em fragmento remanescente de mata atlântica. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.8, n.1, p.9-108, 2014.

FERREIRA, D.F. **SISVAR.** Sistema de Análise de Variância. Versão 5.3. Lavras-MG: UFLA, 2010.

GASPARIN, E.; RICIERI, R.P.; SILVA, S.L.; DALLACORT, R.; GNOATTO, E. Temperatura no perfil do solo utilizando duas densidades de cobertura e solo nu. **Acta Scientiarum Agronomy**, v.27, n.1, p.107-114, 2005.

GONZALEZ-FUENTES, J.A.; SHACKEL, K.; LIETH, J.H.; ALBORNOZ, F.; BENAVIDES-MENDOZA, A.; EVANS, R.Y. Diurnal root zone temperature variations affect strawberry water relations, growth, and fruit quality. **Scientia Horticulturae**, v.203, p.169-177, 2016.

GRASSBAUGH, E.M.; REGNIER, E.E.; BENNETT, M.A. Comparison of organic and inorganic mulch as for heirloom tomato production. **Acta Horticulturae**, v.6, n.38, p.171-176, 2004.

HANSEN, L.D.; BARROS, N.; TRANSTRUM, M.K.; RODRIGUEZ-AÑÓN, J.; PROUPIN, J.; PIÑEIRO, V.; ARIAS-GONZÁLEZ, A.; GARTZIA, N. Effect of extreme temperatures on soil: A calorimetric approach. **Thermochimica Acta**, v.670, [s.n.], p.128-135, 2018.

HILLEL, D. **Introduction to environmental soil physics.** Amsterdam: Elsevier Academic Press, 2004. 494p.

JAMIL, M.; MUNIR, M.; QUASIM, M.; BALOCH, J.; REHMAN, K. Effect of different types of mulches and their duration on the growth and yield of garlic (*Allium sativum* L.). **International Journal of Agricultural and Biological Engineering**, v.7, n.4, p.588-591, 2005.

JOHNSON, J.M.; HOUGH-GOLDSTEIN, J.A.; VANGESSEL, M.J. Effects of straw mulch on pest insects, predators, and weeds in watermelons and potatoes. **Environmental Entomology**, v.1, n.33, p.1632-1643, 2004.

KAR, G.; KUMAR, A. Effects of irrigation and straw mulch on water use and tuber yield of potato in eastern India. **Agricultural Water Management**, v.94, n.109, p.116-118, 2007.

KIEHL, E.J. **Fertilizantes orgânicos.** Piracicaba: Agronômica Ceres, 1985. 492p.

KOCH, O.; TSCHERKO, D.; KANDELER, E. Temperature sensitivity of microbial respiration, nitrogen mineralization, and potential soil enzyme activities in organic alpine soils. **Global Biogeochemical Cycles**, v.21, n.4, p.1-11, 2007.

KOSTERNA, E. Soil mulching with straw in broccoli cultivation for early harvest. **Journal of Ecological Engineering**, v.15, n.2, p.100-107, 2014.

MENESES, N.B.; MOREIRA, M.A.; SOUZA, I.M.; BIANCHINI, F.G. Crescimento e produtividade de alface sob diferentes tipos de cobertura do solo. **Revista Agro@mbiente On-line**, v.10, n.2, p.123-129, 2016.

MOTA, F.S. **Meteorologia Agrícola.** 7a. ed. São Paulo: Nobel, 1983. 376p.
PASSOS, F.A.; TRANI, E.T.; SANCHES, J.; ANTONIALI, S.; WATANABE, A.T.; SEMIS, J.B.; SALOMON, M.V.; BORZACCHINI, O. Morango (*Fragaria* x *ananassa* Duch. ex Rozier). In: AGUIAR, A.T.E.; GONÇALVES, C.; PATERNIANI, M.E.A.G.Z.; TUCCI, M.L.S.; CASTRO, C.E.F. (Eds.). **Instruções agrícolas para as principais culturas econômicas.** 7a. ed. rev. e atual. Campinas: Instituto Agronômico, 2014. (Boletim IAC, 200). p.283-287.
PEREIRA, A.R.; ANGELOCCI, L.R.; SENTELHAS, P.C. Temperatura. In:___. **Agrometeorologia:** Fundamentos e Aplicações Práticas. Guaíba (RS): Livraria e Editora Agropecuária, 2002. 478p.
PEREIRA NETO, J.T. **Manual de compostagem:** processo de baixo custo. Viçosa: UFV, 2007. 81p.
PRADO, H.; TREMOCOLDI, W.A.; MENK, J.R.F. **Levantamento pedológico detalhado do Pólo Regional de Desenvolvimento Tecnológico dos Agronegócios da Alta Paulista, Adamantina (SP).** Campinas: Instituto Agronômico, 2003. 27p. (Série Pesquisa APTA. Boletim Científico, 10).
PREVEDELLO, C.L. **Física do solo com problemas resolvidos.** 1a. ed. Curitiba, Salesward-Discovery, 1996. 446p.
PREVEDELLO, C.L. **Energia térmica do solo.** In: VAN LIER, Q.J (Ed.). Física do solo. Sociedade Brasileira de Ciência do Solo, Viçosa, MG, 2010, p.177-212.
PRIMAVESI, A. **O solo tropical:** casos. Perguntando sobre solo. São Paulo: Fundação Mokiti Okada, 2003. 115p.
QUEIROGA, R.C.F.; NOGUEIRA, I.C.C.; BEZERRA NETO, F.; MOURA, A.R.B.; PEDROSA, J.F. Utilização de diferentes materiais como cobertura morta do solo no cultivo de pimentão. **Horticultura Brasileira**, v.20, n.3, p.416-418, 2002.
RAIJ, B. VAN. A capacidade de troca de cátions das frações orgânica e mineral em solos. **Bragantia**, v.28, n.único, p.85-112, 1969.
RENA, A.B.; GUIMARÃES, P.T.G. **Sistema radicular do cafeeiro:** estrutura, distribuição, atividade e fatores que o influenciam. Belo Horizonte: Epamig, 2000. 80p.
RESENDE, F.V.; SOUZA, L.S.; OLIVEIRA, P.S.R.; GUALBERTO, R. Uso de cobertura morta vegetal no controle da umidade e temperatura do solo, na incidência de plantas invasoras e na produção da cenoura em cultivo de verão. **Ciência e Agrotecnologia**, v.29, n.1, p.100-105, 2005.
RISSER, G.; CORNILLON, P.; RODE, J.C. Effect de la temperature dês racines sur la croissance de jeunes plants de diverses varietés de melon (*Cucumis melo* L.). **Annales d'Agronomie**, v.29, n.5, p.453-473, 1978.
ROTTA, O.U.; JORGE, J.A.; OLIVEIRA, J.B.; KÜPPER, A. Levantamento pedológico detalhado da Estação Experimental de Monte Alegre do Sul, SP. **Bragantia**, v.30, n.2, p.215-252, 1971.
SERRANO JÚNIOR, O.V. Manejo orgânico de solos em fruteiras. In: ENCONTRO BIOMASSA: adubos orgânicos e manejo da biomassa, 2002. **Anais...**Botucatu, SP, 2002. p.107-112.
SHOAIB, M.; AHMAD, M.Z.; ATIF, M.; PARVAIZ, M.; KAUSAR, V.; TAHIR, A.A Review: effect of temperature and water variation on tomato (*Lycopersicon esculentum*). **International Journal of Water Resources and Environmental Sciences**, v.1, n.3, p.82-93, 2012.
SILANS, A.P.; SILVA, F.M.; BARBOSA, F.A.R. Determinação *in loco* da difusividade térmica num solo da região de Caatinga (PB). **Revista Brasileira de Ciência do Solo**, v.30, n.1, p.41-48, 2006.
SILVA, V.R.; REICHERT, J.M.; REINERT, D.J. Variação na temperatura do solo em três sistemas de manejo na cultura do feijão. **Revista Brasileira de Ciência do Solo**, v.30, n.3, p.391-399, 2006.
VOOS, M. SIDIRAS, N. Nodulação da soja em plantio direto em comparação com plantio convencional. **Pesquisa Agropecuária Brasileira**, v.20, n.7, p.775-778, 1985.