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Entries without author names are glossary terms

(Wigneron et al., 1998; Kerr, 2007), and plant and weeds cover (Thorp and Tian, 2004).

Conclusion

Monitoring physical conditions in agriculture and environment can be done in various temporal and dimensional scales and with the application of numerous instruments and methods reflecting the current development of technology. The received and processed data increase our knowledge for the benefit of social, political, and economic sustainable development as well as for better understanding the nature.

Bibliography

Arshad, A. A., and Martin, S., 2002. Identifying limits for soil quality indicators in agro-ecosystems. *Agriculture, Ecosystems and Environment*, **88**, 152–160.

Artiola, J., Pepper, I. L., and Brusseau, M. L., 2004a. Monitoring and characterization of the environment (Chapter 11). In *Environmental Monitoring and Characterization*. Burlington: Elsevier, pp. 1–9.

Artiola, J., Pepper, I. L., and Brusseau, M. L., 2004b. Remote sensing for environmental monitoring (Chapter 11). In *Environmental Monitoring and Characterization*. Burlington: Elsevier, pp. 183–206.

Doran, J. W., 2002. Soil health and global sustainability: translating science into practice. *Agriculture, Ecosystems and Environment*, **88**, 119–127.

Kerr, Y. H., 2007. Soil moisture from space: where are we? *Hydrogeology Journal*, **15**, 117–120.

Malicki, M. A., 1999. Methodical aspects of water status monitoring in selected bio-materials. *Acta Agrophysica (Series Monographs)*, **19** (in Polish).

Malicki, M. A., and Bieganowski, A., 1999. Chronovoltammetric determination of oxygen flux density in the soil. *International Agrophysics*, **13**(3), 273–281.

Rosenqvist, Å., Milne, A., Lucas, R., Imhoff, M., and Dobson, C., 2003. A review of remote sensing technology in support of the Kyoto Protocol. *Environmental Science & Policy*, **6**, 441–455.

Schoenholtz, S. H., Van Miegroet, H., and Burger, J. A., 2000. A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *Forest Ecology and Management*, **138**, 335–356.

Skierucha, W., Wilczek, A., and Walczak, R. T., 2006. Recent software improvements in moisture (TDR method), matric pressure, electrical conductivity and temperature meters of porous media. *International Agrophysics*, **20**, 229–235.

Thorp, K. R., and Tian, L. F., 2004. A review on remote sensing of weeds in agriculture. *Precision Agriculture*, **5**, 477–508.

Wang, N., Zhang, N., and Wang, M., 2006. Wireless sensors in agriculture and food industry – recent development and future perspective. *Computers and Electronics in Agriculture*, **50**, 1–14.

Wigneron, J. P., Schmugge, T., Chanzy, A., Calvet, J. C., and Kerr, Y., 1998. Use of passive microwave remote sensing to monitor soil moisture. *Agronomie*, **18**, 27–43.

Cross-references

Climate Change: Environmental Effects
Nondestructive Measurements in Soil
Online Measurement of Selected Soil Physical Properties
Remote Sensing of Soils and Plants Imagery
Spatial Variability of Soil Physical Properties

MUALEM EQUATION

Model for predicting hydraulic conductivity of unsaturated porous media.

Bibliography

Mualem, Y., 1976. A new model for predicting hydraulic conductivity of unsaturated porous media. *Water Resources Research*, **12**:513–522.

Cross-references

Water Budget in Soil

MULCHING

See *Water Use Efficiency in Agriculture: Opportunities for Improvement*

MULCHING, EFFECTS ON SOIL PHYSICAL PROPERTIES

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Definition

Mulch. Mulch is any material, other than soil, placed or left at the soil surface for soil and water management.

Mulching. In agriculture and gardening, mulching is the practice of leaving crop residues or other materials on the soil surface for soil and water conservation and keeping favorable and stable environments for plant growth.

Introduction

Mulching is a form of conservation tillage consisting of leaving a layer of crop residues (CR) or other materials on the soil surface. Mulch helps to preserve high and sustainable yields by increasing the soil organic matter (SOM) content and therefore improving soil physical quality. Mulch tilling is also a form of minimum tillage and a cost-efficient alternative for high-yield conservation agricultural practice.

Leaving CR or other substances on the soil surface is a traditional practice for protecting soil from erosion and enhancing fertility (Lal and Stewart, 1995). It has been reported that conventional agricultural practices, based on intensive fertilization and chemical amendments, often lead to degradation processes, such as erosion (see entry *Tillage Erosion*), acidification, and the emission of greenhouse gases (see entry *Greenhouse Gases Sink in Soils*). Current global problems such as population growth, greenhouse effect, malnutrition, water quality, reduction of agricultural land, and soil degradation (see entry *Desertification: Indicators and Thresholds*) require the implementation of conservation tillage practices to address the problem of sustainability, food security, and environmental quality.

Materials used as mulch

A wide variety of materials can be used as mulch. Most of mulches are organic materials (e.g., CR, litter, straw, leaves, or weed biomass), but other inorganic or industry-derived materials can be also used (plastic film, gravels, or geotextiles). The election depends in both availability and objectives.

Organic mulches must be weed free, easy to apply, and readily available by farmers. The mulch decomposition time can vary greatly. Depending on the amount and type of mulch, varying quantities of nutrients and organic matter enter the soil during the decomposition process. In agriculture, the most commonly used organic mulches are crop/plant residues, produced on-site or off-site and left on the soil surface after cropping (e.g., wheat straw). A large quantity of residue is produced annually, so that it constitutes a renewable and easily available resource. Other mulches used in agriculture and gardening are wood chips, pine bark, and pine needles. Some wastes, such as shredded or composted clipped grass, litter, and small branches can also be used.

Inorganic materials such as geotextiles can be used as mulch. Some of the advantages of using geotextiles is the prevention of weed growth (at least in a great proportion), and the normal aeration and water exchange. Rock fragments and gravels can be used as inorganic mulch materials. They show low decomposition rates and do not require annual replacement, but cannot be suitable for all crops. Plastic films help control most weeds and contribute to water conservation. Plastic films are used predominantly in extensive crop areas, but show some problems: interruption of air, water, and nutrients flow between the topsoil and the atmosphere, as well as other environmental problems such as disposal of plastic materials.

Effects on soil physical properties

Soil structure and aggregate stability

Soil structure is extremely important for the maintenance of soil quality and productivity. Aggregate stability (AS) affects root density and elongation (see entry *Root Responses to Soil Physical Limitations*), air and water flow and erosion (Amézketa, 1999). Some of the main factors affecting soil aggregation are SOM content (see entry *Soil Aggregates, Structure, and Stability*), texture and moisture content, but external factors as crop type, tillage practices, or microfauna are also important. Long-term tillage affects AS (Angers et al., 1993; Unger et al., 1998; Álvaro-Fuentes et al., 2008), as tillage destroys aggregates leading to a decrease in aggregate size and pore clogging by fine particles. It has been reported that decomposition rates of SOM are lower with minimum tillage and residue retention, and consequently it increases over time (Loch and Coughlan, 1984; Dalal, 1989).

AS is determined by the cohesive forces between particles. Therefore, it can be used as an index of structure and physical soil stability. Soil texture, clay mineralogy, cations, and the quantity and quality of SOM are key factors controlling aggregation. Plant roots (see entry *Plant Roots and Soil Structure*), microorganisms (especially fungi), and organic substances are also involved in the formation of aggregates and AS. AS may vary seasonally (Hillel, 1998) or during tilling. After mulching, increased SOM content contributes to enhance aggregation, as it has been reported under a diversity of climate areas (Mulumba and Lal, 2008; Jordán et al., 2010) even in the short term (Hermawan and Bomke, 1997).

Inorganic mulches (e.g., plastic film) show limited or no effect on soil structure. Zhang et al. (2008), for example, reported that under no tillage, the increase in SOM content and AS in soils under straw cover was higher than under plastic film; in this case, soil quality under plastic mulch was similar or even lower than in non-covered soils. In contrast, geotextiles may increase SOM content, improving topsoil structure and AS (Bhattacharyya et al., 2010).

Bulk density and porosity

The effects of CR on soil bulk density (BD; see entry *Bulk Density of Soils and Impact on their Hydraulic Properties*) are highly variable. Although high BD has been observed under mulch relative to conventional tillage (Bottenberg et al., 1999), decreased bulk densities have also been reported by Oliveira and Merwin (2001) and Ghuman and Sur (2001). In other cases, there is no relationship between mulch rate and BD. This variability may be due to differences in management practices, soil type, and the type of mulch material used in the experiments. However, Mulumba and Lal (2008) found that BD increased for mulching rates between 0 and 5 Mg ha^{-1} wheat straw mulch, but strongly decreased for higher rates.

Pores of different size (see entry *Pore Size Distribution*), shape, and continuity are created by abiotic and biotic factors (Kay and VandenBygaart, 2002). Mulumba and Lal (2008) found that total porosity increased significantly with increase in mulch rate after an 11-year treatment in the USA. Increased porosity due to mulch application has been also reported after shorter periods (Oliveira and Merwin, 2001; Jordán et al., 2010).

Penetration resistance

Many studies have reported greater penetration resistance in soils under no-tillage practices than in other conventionally tilled soils in the upper centimeters, and, generally, penetration resistance is higher under reduced tillage systems with residue cover. Mulch application has a significant effect on penetration resistance but only at certain stages of the crop production. After an experiment with Polish Luvisols under reduced and no-tillage practices, penetration resistance increased in the growing season, causing reduced plant growth and crop yield (Pabin et al., 2003). In this case, straw mulch did not counteract the negative changes in the parameters of the soil strength. According to Bielders et al. (2002), differences in penetration resistance after different treatments are mostly due to differences in intrinsic soil properties (e.g., cohesion, BD).

Crusting and sealing

Plant residues on the soil surface protect it against crusting (Sumner and Stewart, 1992), improving AS and infiltration rates (see entry *Soil Surface Sealing and Crusting*). Le Bissonnais and Arrouays (1997) observed that increasing SOM content decreased soil surface sealing. After a study in western Niger, Bielders et al. (2002) observed low permeability erosion crusts and discontinuous structural crusts with partially exposed clay skins in soils under conventional tillage, in contrast to mulched soils. As it has been reported in stone-covered soils (Martínez-Zavala and Jordán, 2008; Zavala et al., 2010), gravel mulch helps to avoid soil sealing and crusting (Poesen and Lavee, 1994).

The use of plastic film mulches has spread considerably as a way to reverse the low crop yields (e.g., Zhang and Ma, 1994), increasing the risk of crust formation (Li et al., 2005).

Soil temperature

Temperature affects the rate of soil biological and chemical processes (see entry *Temperature Effects in Soil*). The amount of energy entering the soil depends strongly on soil color, aspect, and the vegetative cover. CR on the soil surface can affect or completely modify the soil temperature regime by reducing the amount of energy entering the soil by the interception of radiation, shading the soil surface, and buffering temperature variations.

Soil temperature range is usually narrower in mulched than unmulched soils. Wheat straw has a higher albedo and lower thermal conductivity than bare soil, and therefore it reduces the input of solar energy (Horton et al., 1996). On the other hand, during colder periods, wheat straw mulch on the soil surface insulates it from the colder atmosphere (Zhang et al., 2009).

Results after application of inorganic mulches vary depending on the mulch material. After field experiments in the UK, Cook et al. (2006) demonstrated that soil temperature reduced with higher mulching rates. In contrast, the use of inorganic mulches can increase soil temperature. Nachtergaele et al. (1998) reported that gravel mulch increased soil temperature and decreased evaporation (see entry *Evapotranspiration*) in vineyard soils in Switzerland. Organic geotextiles can also attenuate extreme temperature fluctuations, reducing water loss through evaporation. Inorganic materials such as plastic mulches are often used to increase soil temperature in horticulture, leading to high yields. Apart from other environmental problems, intensive use of plastic mulches for increasing soil temperature shows some limitations. Enhanced mineralization rates can lead to exhaustion of SOM, affecting long-term soil physical and chemical fertility (Li et al., 2004).

Soil water

Mulching has a great impact on soil water and surface water. Mulching decreases runoff by improving infiltration rate and increases water storage capacity by improving retention (see entry *Field Water Capacity*). In addition, reduced evaporation rates help to extend the period of time during which soil remains moist.

Mulching improves considerably soil water characteristics, although different results have been reported. Organic mulches on the soil surface induce optimal soil conditions for plant growth, enhancing soil water retention and availability, and increasing macroporosity (Martens and Frankenberger, 1992). Much research has shown that use of mulch can increase infiltration and decrease evaporation, resulting in more water stored and reduced runoff rates (e.g., Smika and Unger, 1986).

Wheat straw mulch is considered the best way of improving water retention in the soil and reducing soil evaporation. High available water capacities have been reported under high mulching rates and reduced or no till practices. Mulumba and Lal (2008) and Jordán et al. (2010) found that even low mulch rates have a strong impact on the available water content. Contrasting data have been reported by Głąb and Kulig (2008), who found no effect in available water content after applying mulch and different tillage systems. Results can also vary between the upper and lower layers of the soil profile.

Soil erosion risk

Many researchers have reported low or negligible soil losses in mulched soils in comparison with conventional soil tillage (see entry *Water Erosion: Environmental and Economical Hazard*). The hydrological/erosional response of mulched soils depends largely on the mulching rates applied during the crop period. It has been reported that the erosive consequences of moderate storms in the Mediterranean area could be strongly reduced by using just 5 Mg ha^{-1} $year^{-1}$ mulching rates (Jordán et al., 2010). A mulch layer increases the roughness and the interception of raindrops, delaying runoff flow and favoring infiltration (García-Orenes et al., 2009). Low erosive responses of mulched soils have been reported from diverse climate areas of the world. In contrast, Jin et al. (2009) suggested that the relation between mulching rate and interrill soil detachment is not unique and can vary depending on rainfall intensity. Increasing cover rates reduce infiltration and lead to an increasing net flux, which becomes deeper and faster in its concentrated flow part. In this case, ponding is faster and deeper, thus the water column pressure is greater and thereafter infiltration takes place more quickly and penetrates more deeply. However, this response can be overridden under moderate rainfall intensity by a dense soil cover or thick mulch layers.

Plastic mulches substantially accelerate runoff generation in slopes (Wan and El-Swaify, 1999). According to Bhattacharyya et al. (2010), the use of geotextiles is an effective soil conservation practice, but its efficiency decreases in large areas. Despite synthetic geotextiles dominating the commercial market, geotextiles constructed from organic materials are highly effective in erosion control and vegetation establishment (Ogbobe et al., 1998) and can be an ecological alternative for farmers (Giménez-Morera et al., 2010). Anyway, experimental studies under natural and simulated rainfall have demonstrated that cotton geotextiles reduce soil losses but increase water losses, probably due to water repellency of cotton. Although soil erosion can be severely reduced by geotextiles at the pedon or meter scale, surface runoff may result in high erosion rates at slope and watershed scales as more runoff will be available (Giménez-Morera et al., 2010).

Summary

During the last decades, conservation tillage techniques have displaced conventional tillage in many areas of the world. The use of CR left on the soil surface improves soil quality and productivity through favorable effects on soil physical properties. Mulch farming is a form of conservation tillage that preserves soil quality and the environment. Mulch affects soil physical properties by improving SOM content, increasing soil porosity and AS. Indirectly, mulching also regulates soil temperature, and increases water retention capacity.

An organic mulch layer serves as a protecting layer against rainfall-induced soil erosion by reducing drop impacts and modifying the hydrological response of the exposed surface. CR and other organic mulches intercept rainfall and contribute to decrease runoff rates and enhance infiltration, protecting soil from erosion. Inorganic mulches as geotextiles, gravels, or plastic films show a range of erosional responses to rainfall.

Bibliography

Álvaro-Fuentes, J., Arrúe, J. L., Gracia, R., and López, M. V., 2008. Tillage and cropping intensification effects on soil aggregation: temporal dynamics and controlling factors under semiarid conditions. *Geoderma*, **145**, 390–396.

Amézketa, E., 1999. Soil aggregate stability: a review. *Journal of Sustainable Agriculture*, **14**, 83–151.

Angers, D. A., Samson, N., and Légère, A., 1993. Early changes in water-stable aggregation induced by rotation and tillage in a soil under barley production. *Canadian Journal of Soil Science*, **73**, 51–59.

Bhattacharyya, R., Smets, T., Fullen, M. A., Poesen, J., and Booth, C. A., 2010. Effectiveness of geotextiles in reducing runoff and soil loss: a synthesis. *Catena*, **81**, 184–195.

Bielders, C. L., Michels, K., and Bationo, A., 2002. On-farm evaluation of ridging and residue management options in a Sahelian millet-cowpea intercrop. 1. Soil quality changes. *Soil Use and Management*, **18**, 216–222.

Bottenberg, H., Masiunas, J., and Eastman, C., 1999. Strip tillage reduces yield loss of snapbean planted in rye mulch. *HortTechnology*, **9**, 235–240.

Cook, H. F., Valdes Gerardo, S. B., and Lee, H. C., 2006. Mulch effects on rainfall interception, soil physical characteristics and temperature under *Zea mays* L. *Soil and Tillage Research*, **91**, 227–235.

Dalal, R. C., 1989. Long-term effects of no-tillage, crop residue, and nitrogen application on properties of a Vertisol. *Soil Science Society of America Journal*, **53**, 1511–1515.

García-Orenes, F., Cerdà, A., Mataix-Solera, J., Guerrero, C., Bodí, M. B., Arcenegui, V., Zornoza, R., and Sempere, J. G., 2009. Effects of agricultural management on surface soil properties and soil-water losses in eastern Spain. *Soil and Tillage Research*, **106**, 117–123.

Ghuman, B. S., and Sur, H. S., 2001. Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate. *Soil and Tillage Research*, **58**, 1–10.

Giménez-Morera, A., Ruiz Sinoga, J. D., and Cerdà, A., 2010. The impact of cotton geotextiles on soil and water losses from Mediterranean rainfed agricultural land. *Land Degradation and Development*, **21**, 210–217.

Głąb, T., and Kulig, B., 2008. Effect of mulch and tillage system on soil porosity under wheat (*Triticum aestivum*). *Soil and Tillage Research*, **99**, 169–178.

Hermawan, B., and Bomke, A. A., 1997. Effects of winter cover crops and successive spring tillage on soil aggregation. *Soil and Tillage Research*, **44**, 109–120.

Hillel, D., 1998. *Environmental Soil Physics*. San Diego: Academic.

Horton, R., Bristow, K. L., Kluitenberg, G. J., and Sauer, T. J., 1996. Crop residue effects on surface radiation and energy balance – review. *Theoretical and Applied Climatology*, **54**, 27–37.

Jin, K., Cornelis, W. M., Gabriels, D., Baert, M., Wu, H. J., Schiettecatte, W., Cai, D. X., De Neve, S., Jin, J. Y., Hartmann, R., and Hofman, G., 2009. Residue cover and rainfall intensity effects on runoff soil organic carbon losses. *Catena*, **78**, 81–86.

Jordán, A., Zavala, L. M., and Gil, J., 2010. Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. *Catena*, **81**, 77–85.

Kay, B. D., and VandenBygaart, A. J., 2002. Conservation tillage and depth stratification of porosity and soil organic matter. *Soil and Tillage Research*, **66**, 107–118.

Lal, R., and Stewart, B. A., 1995. *Soil Management – Experimental Basis for Sustainability and Environmental Quality*. Boca Raton: Lewis. Advances in Soil Science.

Le Bissonnais, Y., and Arrouays, D., 1997. Aggregate stability and assessment of soil crustability and erodibility. II. Application to humic loamy soils with various organic carbon contents. *European Journal of Soil Science*, **48**, 39–48.

Li, F. M., Wang, J., Xu, J. Z., and Xu, H. L., 2004. Productivity and soil response to plastic film mulching durations for spring wheat on entisols in the semiarid Loess Plateau of China. *Soil and Tillage Research*, **78**, 9–20.

Li, L. L., Huang, G. B., Zhang, R. Z., Jin, X. J., Li, G. D., and Chan, K. Y., 2005. Effects of conservation tillage on soil water regimes in rainfed areas. *Acta Ecologica Sinica*, **25**, 2326–2332.

Loch, R. J., and Coughlan, K. J., 1984. Effects of zero tillage and stubble retention on some properties of a cracking clay. *Australian Journal of Soil Research*, **22**, 91–98.
Martens, D. A., and Frankenberger, W. T., 1992. Modification of infiltration rates in an organic-amended irrigated soil. *Agronomy Journal*, **84**, 707–717.
Martínez-Zavala, L., and Jordán, A., 2008. Effect of rock fragment cover on interrill soil erosion from bare soils in Western Andalusia, Spain. *Soil Use and Management*, **24**, 108–117.
Mulumba, L. N., and Lal, R., 2008. Mulching effects on selected soil physical properties. *Soil and Tillage Research*, **98**, 106–111.
Nachtergaele, J., Poesen, J., and van Wesemael, B., 1998. Gravel mulching in vineyards of southern Switzerland. *Soil and Tillage Research*, **46**, 51–59.
Ogbobe, O., Essien, K. S., and Adebayo, A., 1998. A study of biodegradable geotextiles used for erosion control. *Geosynthetics International*, **5**, 545–553.
Oliveira, M. T., and Merwin, I. A., 2001. Soil physical conditions in a New York orchard after eight years under different groundcover management systems. *Plant and Soil*, **234**, 233–237.
Pabin, J., Lipiec, J., Włodek, S., and Biskupski, A., 2003. Effect of different tillage systems and straw management on some physical properties of soil and on the yield of winter rye in monoculture. *International Agrophysics*, **17**, 175–181.
Poesen, J. W. A., and Lavee, H., 1994. Rock fragments in top soils: significance and processes. *Catena*, **23**, 1–28.
Singh, B., Chanasyk, D. S., McGill, W. B., and Nyborg, M. P. K., 1994. Residue and tillage management effects on soil properties of a typic cryoboroll under continuous barley. *Soil and Tillage Research*, **32**, 117–133.
Smika, D. E., and Unger, P. W., 1986. Effect of surface residues on soil water storage. *Advanced Soil Science*, **5**, 111–138.
Sumner, M. E., and Stewart, B. A., 1992. *Soil Crusting – Chemical and Physical Processes*. Boca Raton: Lewis. Advances in Soil Science.
Unger, P. W., Jones, O. R., McClenagan, J. D., and Stewart, B. A., 1998. Aggregation of soil cropped to dryland wheat and grain sorghum. *Soil Science Society of America Journal*, **62**, 1659–1666.
Wan, Y., and El-Swaify, S. A., 1999. Runoff and soil erosion as affected by plastic mulch in a Hawaiian pineapple field. *Soil and Tillage Research*, **52**, 29–35.
Zavala, L. M., Jordán, A., Bellinfante, N., and Gil, J., 2010. Relationships between rock fragment cover and soil hydrological response in a Mediterranean environment. *Soil Science and Plant Nutrition*, **56**, 95–104.
Zhang, S. F., and Ma, T. L., 1994. Yield components and cultivation technology of corn with high grain yield through plastic film cover in West Yellow River area. *Gansu Agricultural Science and Technology*, **1**, 16–17.
Zhang, Z., Zhang, S., Yang, J., and Zhang, J., 2008. Yield, grain quality and water use efficiency of rice under non-flooded mulching cultivation. *Field Crops Research*, **108**, 71–81.
Zhang, S., Lövdahl, L., Grip, H., Tong, Y., Yang, X., and Wang, Q., 2009. Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of China. *Soil and Tillage Research*, **102**, 78–86.

Cross-references

Bulk Density of Soils and Impact on their Hydraulic Properties
Desertification: Indicators and Thresholds
Evapotranspiration
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Soil Surface Sealing and Crusting
Temperature Effects in Soil
Tillage Erosion
Water Erosion: Environmental and Economical Hazard

MUNSELL COLOR SYSTEM

A color designation system that specifies the relative degrees of the three simple variables of color: hue, value, and chroma.

Cross-references

Color in Food Evaluation
Color Indices, Relationship with Soil Characteristics

MYCORRHIZAL SYMBIOSIS AND OSMOTIC STRESS

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Definition

The term Mycorrhiza comes from the Greek words “mycos,” meaning fungus and “rhiza,” meaning root and applies to a mutualystic symbiosis between roots of most higher plants and a group of soil fungi belonging to the phyla Glomeromycota, Basidiomycota or Ascomycota. By this mutualystic association, the plant receives soil nutrients (especially phosphorus) and water, while the fungus receives a protected ecological niche and plant-derived carbon compounds for its nutrition (Varma, 2008).

The term Osmotic Stress refers to all the environmental conditions that induce a water deficit in the plant tissues, limiting plant growth and development. It generally includes drought, cold and salinity, which directly decreases the plant water content due to an also low soil water content (drought) or which difficult the right uptake of water from soil due to the diminution of soil water potential (cold and salinity).

Eco-physiological studies investigating the role of the mycorrhizal symbiosis against osmotic stresses have demonstrated that the symbiosis often results in altered rates of water movement into, through, and out of the host plants, with consequent effects on tissue hydration and plant physiology (Augé, 2001). Thus, it is accepted that the mycorrhizal symbiosis protects host plants against the detrimental effects of water deficit, and that this protection results from a combination of physical, nutritional and