Adv. Soil ,water plant relation for PhD students 1,11,202 forestry Dept..

Explain the following:
1- What is the role of water in plant growth?
2-How is water held in soil against the gravitational force?
3-Can air drying remove hygroscopic moisture from the soil?
4-Whether gravitational and hygroscopic moisture is available to plants?
5-Why do clayey soils have high water holding capacity compared to sandy soil?
6- How does water affect soil microorganisms?
7-What is water potential?
8-What is the soil water potential?
9-Why water potential always negative?

10-Why is osmotic potential always negative?
11-Why is matric potential negative?
12-Why is gravitational potential not always negative?
13-Which of the components of water potential are of importance to soil microorganisms?
14-Are plants able to meet their water requirement through capillary rise from deeper layer of soil ?
15-What makes a water molecule to behave as dipole ?
16- Can water molecules exist individually?
17-Give brief account of factors affecting soil water holding capacity.

I. WHY STUDY SOIL-PLANT-WATER RELATIONS? A. Population Of the four soil physical factors that affect plant growth (mechanical impedance, water, aeration, and temperature) (Shaw, 1952; Kirkham, 1973), water is the most important. Drought causes 40.8% of crop losses in the United States, and excess water causes 16.4%; insects and diseases amount to 7.2% of the losses (Boyer, 1982). In the United States, 25.3% of the soils are affected by drought, and 15.7% limit crop production by being too wet (Boyer, 1982). People depend upon plants for food. Because water is the major environmental factor limiting plant growth, we need to study soil-plant-water relations to provide food for a growing population. What is our challenge? The earth's population is growing exponentially. The universe is now considered to be 13 billion years old (Zimmer, 2001). The earth is thought to be 4.45 billion years old (Allègre and Schneider, 1994). The earth's oldest rock is 4.03 billion years old (Zimmer, 2001). Primitive life existed on earth 3.7 billion years ago, according to scientists studying ancient rock formations harboring living cells (Simpson, 2003). Human-like animals have existed on earth only in the last few (less than 8) million years. In Chad, Central Africa, six hominid specimens, including a nearly complete cranium and fragmentary lower jaws, have been found that are 6 to 7 million years old (Brunet et al., 2002; Wood, 2002). In 8000 B.C., at the dawn of agriculture, the world’s population was 5 million (Wilford, 1982). At the birth of Christ in 1 A.D., it was 200 million. In 1000, the population was 250 million (National Geographic, 1998a) (Fig. 1.1). By 1300, it had grown larger (Wilford, 1982). But by 1400, the population had dropped dramatically due to the Black Death, also called the bubonic plague (McEvedy, 1988), which is caused by a bacillus spread by fleas on rats. The Black Death raged in Europe between 1347 and 1351 and killed at least half of its population. It caused the depopulation or total disappearance of about 1,000 villages. Starting in coastal areas, where rats were on ships, and spreading inland, it was the greatest disaster in western European history (Renouard, 1971). People fled to the country to avoid the rampant spread of the disease in cities. The great piece of literature, The Decameron, published in Italian in 1353 and written by Giovanni Boccaccio (1313–1375), tells of 10 people who in 1348 went to a castle outside of Florence, Italy, to escape the plague. To pass time, they each told a tale a day for 10 days (Bernardo, 1982).

4,469,934,000. In 1985, it was 4.9 billion, and in 1987 it was 5.0 billion (New York Times, 1987). In 1999, the world's population reached 6 billion (National Geographic, 1999). In 2002, the population of the USA was 284,796,887 (Chronicle of Higher Education, 2002). Note that it took more than six million years for humans to reach the first billion; 120 years to reach the second billion; 32 years to reach the third billion; and 15 years to reach the fourth billion (New York Times, 1980). It took 12 years to add the last billion (fifth to sixth billion, 1987 to 1999). The United Nations now estimates that world population will be between 3.6 and 27 billion by 2150, and the difference between the two projections is only one child per woman (National Geographic, 1998b). If fertility rates continue to drop until women have about two children each—the medium-range projection—the population will stabilize at 10.8 billion. If the average becomes 2.6 children, the population will more than quadruple to 27 billion; if it falls to 1.6, the total will drop to 3.6 billion. The population may also fall due to plagues (Weiss, 2002) such as the one that devastated Europe in the fourteenth century.

Current potential plagues may result from AIDS (acquired immune deficiency syndrome), generally thought to be caused by a virus; influenza, another viral infection—for example, there may be a recurrence of the 1918 pandemic (Gladwell, 1997); sudden acute respiratory syndrome (SARS), a deadly infectious disease caused by a coronavirus (Lemonick and Park, 2003); and mad-cow disease, which is formally called bovine spongiform encephalopathy (BSE). BSE is called Creutzfeldt-Jakob (also spelled as CreutzfeldtJacob) disease (CJD), when it occurs in humans (Hueston and Voss, 2000). It is thought to be caused by prions, which were discovered by Stanley Prusiner (1942–) of the University of California School of Medicine in San Francisco; the discovery won Prusiner both the Wolf Prize (1996) and the Nobel Prize (1997) in medicine. Prions are a new class of protein, which, in an altered state, can be pathogenic and cause important neurodegenerative disease by inducing changes in protein structure. Prions are designed to protect the brain from the oxidizing properties of chemicals activated by dangerous agents such as ultraviolet light.

B. The "**Two-Square-Yard Rule**" The population is limited by the productivity of the land. There is a space limitation that our population is up against. Many of us already have heard of this limitation, which is a space of two square yards per person. The sun's energy that falls on two square yards is the minimum required to WHY STUDY SOIL-PLANT-WATER RELATIONS? 3 provide enough energy for a human being's daily ration. Ultimately, our food and our life come from the sun's energy. The falling of the sun's energy on soil and plants is basic. We want to make as many plants grow on those two square yards per person as possible, to make sure we have enough to eat. Let us do a simple calculation to determine how much food can be produced from two square yards, using the following steps:

1. Two square yards is 3 feet by 6 feet or 91 cm by 183 cm. 91 cm × 183 cm = 16,653 cm2 or, rounding, 16,700 cm2.
2. The solar constant is 2.00 cal cm−2 min−1, or, because 1 langley = 1 cal cm−2, it is 2.00 langleys min−1. The langley is named after Samuel Pierpoint Langley (1834–1906), who was a US astronomer and physicist who studied the sun. He was a pioneer in aviation.

The solar constant is defined as the rate at which energy is received upon a unit surface, perpendicular to the sun's direction in free space at the earth's mean distance from the sun (latitude is not important) (Johnson, 1954). The brightness of the sun varies during the 11-year solar cycle, but typically by less than 0.1% (Lockwood et al., 1992). 3. 16,700 cm^2 × 2.00 cal cm^{-2} min^{-1} = 33,400 cal min^{-1}. 4. 33,400 cal min^{-1} × 60 min h^{-1} × 12 h d^{-1} = 24,048,000 cal d^{-1}, or, rounding, 24,000,000 cal d^{-1}. We multiply by 12 h d^{-1}, because we assume that the sun shines 12 hours a day. Of course, the length the sun shines each day depends on the day of the year, cloudiness, and location. 5. There is 6% conversion of absorbed solar energy into chemical energy in plants (Kok, 1967). This 6% is for the best crop yields achieved; 20% (Kok, 1967) to 30% (Kok, 1976) conversion is thought possible, but it has not been achieved; 2% is the conversion for normal yields; under natural conditions, ≤1% is converted (Kok, 1976). The solar energy reaching the earth's surface that plants do not capture to support life is wasted as heat (Kok, 1976). Let us assume a 6% conversion: 24,000,000 cal d^{-1} × 0.06 = 1,440,000 cal d^{-1}.

6. The food “calories” we see listed in calorie charts are in kilocalories. So, dividing 1,440,000 cal d^{-1} by 1,000, we get 1,440 kcal d^{-1}, which is not very much. The following list gives examples of calories consumed per day in different countries (Peck, 2003): 4 1. INTRODUCTION Location Kilocalories d^{-1} USA, France >3,500 Argentina 3,000–3,500 Morocco 2,500–2,999 India 2,000–2,499 Tanzania <2,000

We recognize that the above calculation of productivity from two square yards is simplified, and more complex and thorough calculations of productivity, which consider geographic location, sky conditions, leaf display, and other factors, have been carried out (e.g., de Wit, 1967). Nevertheless, the 1,440 kcal d^{-1} is a useful number to know. It would be a starvation diet. One could live on it, but the calories probably would not provide enough for active physical work, creative intellectual activity, and reproduction. Women below a minimum weight cannot reproduce (Frisch, 1988). Civilization would advance slowly with this daily ration. People begin to die of starvation when they lose roughly a third of their normal body weight. When the loss reaches 40%, death is almost inevitable. Triage is a system developed in World War I. It is the medical practice of dividing the wounded into survival categories to concentrate medical resources on those who could truly benefit from them and to ignore those who would die, even with treatment, or survive even without it. This practice has been advocated to allocate scarce food supplies. Wealthy countries should help only the most promising of the poorer countries since spreading precious resources too thin could jeopardize chances for survival of the strong as well as the weak. If we can grow more food, then this system does not need to be put into effect. In this book, we seek a better understanding of movement of water through the soil-plant-atmosphere continuum, or SPAC (Philip, 1966), because of the prime importance of water in plant growth.

We focus on principles rather than review the literature. Many references are given, but no attempt is made to cite the most recent papers. Articles explaining the principles are cited. They often are in the older literature, but we need to know them to learn the principles. No knowledge of calculus is required to understand the equations presented. In this book, we divide the movement of water through the SPAC into three parts: 1) water movement in the soil and to the plant root; 2) water movement through the plant, from the root to the stem to the leaf; and 3) water movement from the plant into the atmosphere. However, before WHY STUDY SOIL-PLANT-WATER RELATIONS? 5 we turn to principles of water movement in the SPAC, let us first consider plant growth curves.

Soil water

- Soil water is critical to plant growth and development; it is the solvent in which soil nutrients are dissolved before they can be absorbed by plant roots.

Water occurs in three liquid forms:

1. **Capillary water**:

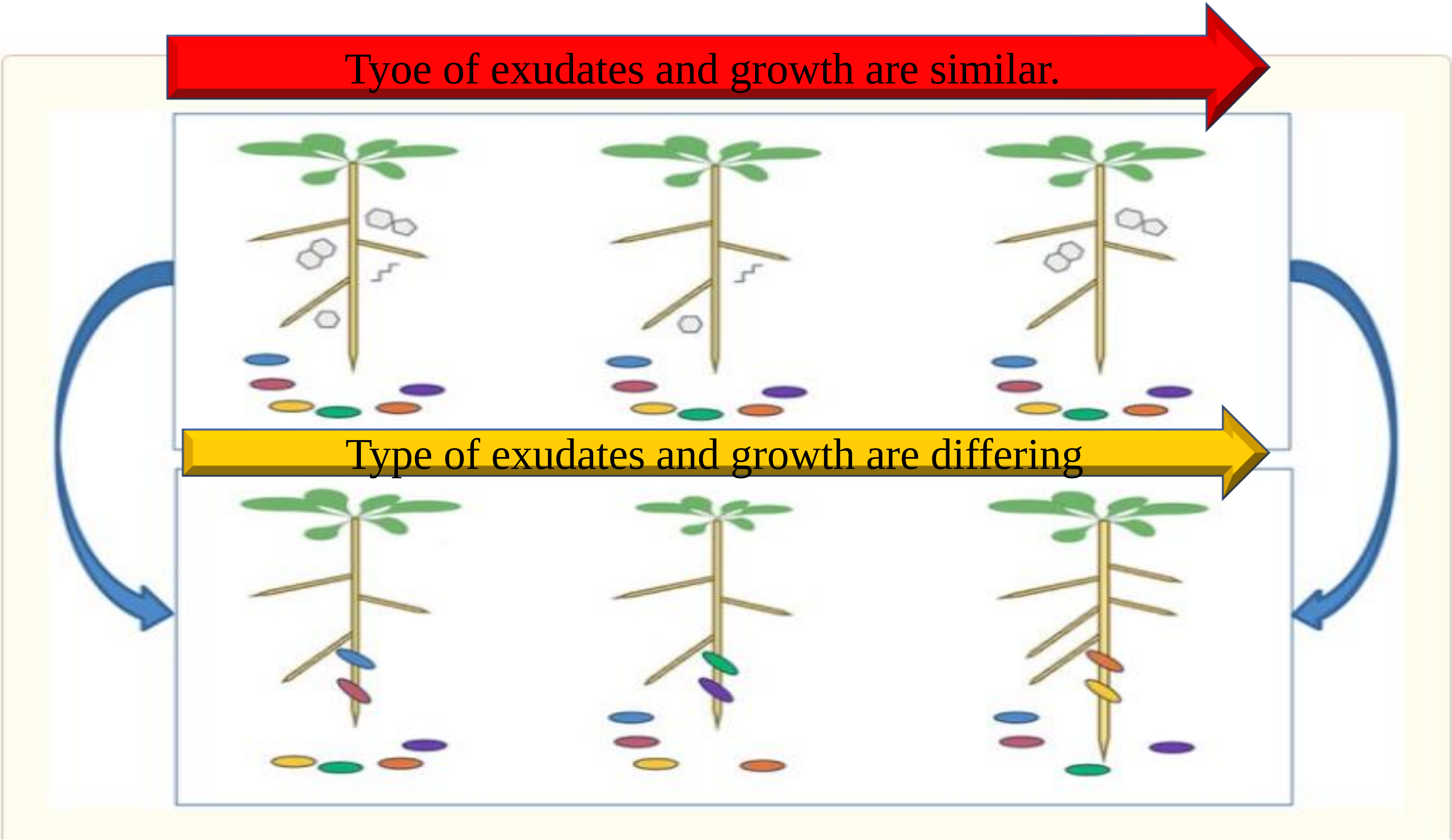
Is the water mainly used by plants ,when the plants will , the soil may still contain 2-17 %moisture ,depending upon its texture and humus content .

2.Gravitational water:

Is that which moves downward by gravity and may percolate beyond reach of the roots of crop plants . متواجدة فى الفراغات الكبيرة

3.Hygroscopic water :

Which Is retained by an air –dry soil kept in a saturated atmosphere .is absorbed on soil particles with such force that it is not available to plant .



Effect of plant exudate on soil microbial activity ,then plant growth.

6.3 The Soil–Plant–At mosphere Continuum (SPAC)2

The flow of water through the SPAC is a major component of the overall hydrologic cycle.
Figure (in the next slide) ties together many of the processes we have just discussed: *interception, surface*
runoff, percolation, drainage, evaporation, plant water uptake, ascent of water to plant leaves, and
Transpiration of water from the leaves back into the atmosphere.

Water Potentials. In studying the SPAC, scientists have discovered that the same basic principles govern the retention and movement of water whether it is in soil, in plants, or in the atmosphere. In Chapter 5, we learned that water in soil moves to where its potential energy level will be lower. This principle applies to water movement between the soil and the plant root and between the plant and the atmosphere (see Figure). If a plant is to absorb water from the soil, the water potential must be lower (greater negative value) in the plant root than in the soil adjacent to the root. Likewise, movement up the root and stem to the leaf cells is in response to differences in water potential, as is the movement from leaf surfaces to the atmosphere. To illustrate the movement of water to sites of lower and lower water potential, Figure 6.17 shows that water potentials might drop from -50 kPa in the soil, to -70 kPa in the root, to -500 kPa at the leaf surfaces, and, finally, to -20,000 kPa in the atmosphere.