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Original Article

Root Distribution and Quantification of Available Water Holding Capacity of Soils

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Abstract

Good productivity is conferred by good physical conditions defined in terms of texture, porosity, bulk densities little above that of water to reduce erosion by moving water, good aggregation, good infiltration rates and good drainage. Soil physical, chemical and physio-chemical conditions determine root proliferation and their activities for nutrient and water uptake and, soil aeration and bioactivity for sustainable productivity . The factors which influence uptake of nutrients and water are discussed with special reference to quantification of rooting depth and water stored in soils against gravity which is used for overall growth after the cessation of rain/ irrigation till next rains /irrigation.

Keywords

Root Distribution; Factors Affecting; Mathematical Model.

Introduction

Various factors, such as gravitropism chemotropism hydrotropism, climatic conditions, soil compactness management practices and communication systems within the plant to change their activities according to the seasonal needs, which affect/ or influence the three dimension root proliferation in soil profile are studied in detail in relation to productivity, Mathematical models are reported on root proliferation to quantify their significance in production models.

The amount of nutrients absorbed by the plants under field conditions depends on:

1. Shoot growth and associated root growth pattern,
2. Water movement in the soil profile,
3. Nutrients movement and balance in the soil profile.

Root growth and distribution in the soil profile depend on the response to shoot growth and demands made by it. Roots react sharply to the requirements of shoots in tune to the growing conditions imposed by climate changes.

A: Agronomic factors

The planting density is one of the important factors which influence root distribution.

1. Low density: It favors shallow rooting due to lack of competition.
2. Medium density: It results in maximum exploitation of space and maximum root density per unit space.
3. High density: It limits the size of individual plants, and induces deep rooting. It is more suitable for cultivars with acutely orthotropic growing habits. It has been reported that the roots of one plant are expelled from the root zone of the neighboring plants and hence roots grow vertically down with increasing plant density.

B: Nutrition factor

1. N & P encourage rooting locally. P is immobile in soil and roots go in search of it and, put out seasonal roots around it which incidentally help in absorption of other nutrients also.

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2. Placement of fertilizers increases rooting in the sub soil where moist conditions remains for a longer time.
3. With good nutrition, the rooting depth increases because of the mobility of nutrients and chemotropism of roots.

C: Temperature and seasonal effects

1. There is a burst of growth in seasonal roots in Spring and Autumn in response to entering into favorable growing conditions.
2. New roots (less than 5mm thick) form about 25 to 30 %of total weight of shoots at any one time. Normally 75 % of the roots are more than 5mm thick. The absorption rate is several times higher in seasonal roots than the thick older ones because of their larger surface area per unit mass. Contribution by thick and old roots is also considerable because of their proportion and their continued activity throughout the year. Seasonal roots supplement the high demand for nutrients and water during growing periods. Extension of root occurs to lower depths as demand for resources increases.
3. Under normal conditions mean life of seasonal root varies between 10 and 12 months in temperate zones and much higher in humid tropics. Seasonal surface roots put out under moist conditions following continuous rain or over watering die off when the soil starts drying.
4. Root length /unit surface area varies between 10 and 1000 cm and weight between 1 and 10 mg per cm^2 of soil surface.
5. Root growth is associated with shoot activity and the communication system between them has been studied extensively in recent times. Shoot growth is therefore used in crop logging systems for applying nutrients and planning irrigation schedules.

D: Water Relations

1. Increased watering and humid conditions favors shallow rooting.
2. Withholding irrigations and /or lengthening irrigation intervals induces deep rooting.
3. Intermittent exposure to drought conditions result in roots exploring lower strata for survival. This is the reason for exposing young plants after planting to intermittent dry spells for inducing drought hardiness in them.

E: Soil structure and tillage

1. Surface compaction is not generally a problem as it is cured by tilling every season before sowing/ planting.
2. Surface compaction prevents sub-soil compaction. But evidence for sub-soil compaction comes from measurements of bulk densities or penetrometer resistance. Sub-soil compaction gives resistance to root proliferation and movement of nutrients and water. It can be cured by sub-soil tilling if the situation really wants it. Zero tillage practices prevent sub-soil compaction, Modern trend is to go for minimum or zero tillage practices.
3. Kaolinite soils with non-expanding, planar silicate structure do not compact as much as illite soils or Montmoriuonite soils with expanding three dimensional molecular structure.

F: Pests and diseases

1. Lesions of Take all fungus (*Ganmannomyces Graminis*) , when formed, cuts large parts of root systems in Ceraels.
2. Damping off (*Rhizoctonia or Pythium*) causes rotting of root system in many crops.
3. Nematodes *(Longidorous&Trichodorus sp.,)* damages root system leading to symptoms of N & Mg deficiencies.
4. Root-knot nematodes (*Heterodorus sp.)*Leads to wilting of plants due to poor root formation.
5. Rats chew bark of roots leading to ultimate death of plants.

Mathematical models for root distribution in the soil

Several mathematical models for root distribution have been brought out from time to time; exponential model of Gerwitz and Page (1974) and Nielsen and Mackenthin (1991) are widely used because of their simplicity for quantifying the effect of root distribution for use in production programs. Gerwitz and Page assumed exponential decline in root length density with depth and developed simple relation to assess the percentage of roots between the surface and any soil depth . Nielson and Mackenthin extended it to the root intensity of single trees a with the distance from its base and it is useful to decide on spacing of plants, nutrition and management practices in orchards, coconut gardens and forestry Root distribution according to Gerwitz and Page decreases with depth and it could be expressed by the equation;

$P_Z = 100\ (1- e^{-FZ})$

P_Z is the percentage root distribution in the profile up to the depth "Z" cm and "F" is equal to 1/Z where "Z" is a depth with 63 % root distribution (in some cases it is 70 %).

Data on root distribution reported in various reports on various occasions in different tea growing areas are used to develop a model for root distribution that can be used to estimate the water stored in soil pores against the gravity to a depth where 90 % of roots are seen, With evapo-transpiration rates ,one could easily estimate the length of drought period that the plants can tolerate in a given area for their survival.

Some of the root distribution patterns , so arrived for different tea growing areas are given in Table I

Table 1: Patterns of root distribution in various tea growing areas

Depth cm	Cumulative root distribution %			South Indian(Mean-root distribution %)	
	A	B	C	Calculated	Recorded
30	40	35	57	40	50
60	63	58	82	65	75
90	78	72	92	80	90
120	86	80	97	87	95
150	92	86	-	92	98
180	95	92	-	95	100
210	-	-	-	98	-
210+	-	-	-	100	-
F	0.0167	0.0148	0.0285	0.0179	0.0256
Depth for 63 %distribution	60 cm	70 cm	35 cm	56 cm	39 cm
Depth for 90% distribution	138 cm	161 cm	81 cm	129 cm	90 cm

A Wynaad-clayey soil with five months drought ; Loamy soils in Anamallais and vandiperiyar area with 3 to 4 months drought
B Drier area in Karnataka
C Areas with well distributed rainfall with less than two months drought – Highwavys, Singampatti, and Assam (Bramhaputra valley)

Normally the water available to a depth explored by 90 % roots is considered to be available for survival and growth of plants when entering into a dry period. Most of the crops including Tea, 90% roots distribution is seen between surface and up to a depth of 150 cm. The mean water holding capacity of soil is 48 % when this converted to equivalent of rainfall, the water stored in the soils amounts to 72 cm.

Available water is the difference between maximum water holding capacity (Field capacity0 and the wilting point water contents. The matric potential of soil moisture available to plants lies between -1/10 to – 1/3 bar. The available moisture is generally around 70 % of the field capacity. It brings down the available water storage to 50.4 cm rainfall (70 % of 72 cm).

Again root distribution intensity decreases with depth. As such water in upper layers is exploited more efficiently than those at lower layers. Exponential decrease in probability of water exploitation at different layers due to decrease in root intensity layer by layer with depth leads to around 70 % of available water being available to plants. This further brings down the net available water stored to 35.28 cm (70 % of 50.4).

For soils under good management, it is taken as an equivalent to 36 cm rainfall. Evapotranspiration rate in tea growing areas in Southern India varies 5 to 7 cm per month during dry seasons. As such the bushes could survive through 5 to 6 dry months.

This is further facilitated by inducing deep rooting by inadvertent exposure to drought over the years and sub–soil irrigation during dry months in the initial years of establishment of plants.

Summing up

Gerwitz and Page model is applied to root distribution in tea growing soils for determining their potential to store water which will be used by roots for their various functions to sustain growth of plants for varying periods between two successive rains or irrigations

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