Effective rooting depth of mustard under dryland conditions.

L. C. Dharmasri, E. de Jong, and L. E. Cowell, Dept. of Soil Science, University of Saskatchewan.

Effective rooting depth of mustard under dryland conditions.

L. C. Dharmasri, E. de Jong, and L. E. Cowell, Dept. of Soil Science, University of Saskatchewan.

We conducted a field study to investigate the effective rooting depth of mustard (Brassica juncea L. Coss.). The data on effective depth of root water extraction and root distribution are needed in understanding and modelling root-soil-water interactions and to use in soil water balance estimations.

Data was collected from upper and lower slope positions in a mustard field. Soil water content was determined using neutron moderation (10- to 120-cm profile). Soil water content - time curves were used to identify the effective depths of root water depletion ("effective rooting depth"). Root distribution and the maximum rooting depth were measured with the trench profile method.

For both slope positions maximum water depletion depths were deeper than the actual rooting depth at the early growth stage. This may be due to the upward water migration. Maximum rooting depth for mustard reached up to 150 cm at upper slope position but the effective rooting depth was found around 120 cm. This may be due to low rooting density at the bottom of the root zone at upper slope. At the lower slope, water depletion depth reached 100 cm only for a short duration and was usually around 60 - 80 cm.

Introduction:

The root system and its development play a substantial role in determination of the water status of both the plant and the soil. The root system must meet the demand in water loss by transpiration, and specify the intensity of the sink term in the dynamics of water transport in the soil (Protopapas and Bras, 1987). The availability and extraction of soil moisture by the crop is highly dependent on rooting depth and proliferation. Deeper rooting increases water availability, and root proliferation increases water extraction from a unit volume of soil before permanent wilting occurs. Water extraction rates depend on evaporative demand, soil water potential, and soil hydraulic characteristics (Gardner, 1985).

The effective rooting depth may vary with soil type. Most root system models assume knowledge of the root zone depth during the growing season (Protopapas and Bras, 1987). The efficiency of soil water extraction is an important factor determining crop productivity in dryland conditions.

Root patterns of different crop varieties help to explain yield performances at different moisture levels (Hurd, 1968). Hurd (1968) also indicated the varietal differences in root growth for wheat and reported that roots penetrated the soil more quickly in dry soil than in wet soil. Comparisons of rooting depth and water depletion depth have been reported for different crops (Durrant et al.,1973; Allmaras et al., 1975; Stone et al.,1976; Gregory et al.,1978; Entz et al.,1992).

Passioura (1981) indicated in a review that roots fail to extract large amounts of apparently available water from the soil at the bottom of the rooting zone, even though the plants were suffering from drought. He also reported the possible reasons for this behavior, which could be due to a large axial resistance in the roots, inadequate rooting density, or low permeability of the deep roots.

McGowan (1974) assessed soil moisture with a neutron probe, and the water content - time curves for individual soil depths were used to identify the point at which rate of water loss starts to increase representing the arrival of a drying front associated with root water extraction. He also reported the depth of soil to which accelerated rate of soil drying is observed can be considered as an "effective rooting depth" at that point of time. The weakness of this method its dependence on weather as dry spells are required to establish the drying curves (McGowan, 1974).

The present study was conducted to investigate the maximum root and water depletion depths of mustard at different slope positions in a soil catena under dryland conditions.

Materials and methods :

Description of experimental site

This investigation was carried out at Bradwell Saskatchewan. Brown mustard was seeded in rows with spacing of 15 cm on May 29, 1992. The crop was entirely rainfed. Upper and lower slope positions were selected along the same soil catena in a field. The slope extended approximately 60 m, with a 4% gradient. A 40 m^2 plot was maintained at each location.

The soil in the plot vicinity is mapped as a Bradwell fine sandy loam. Thickness of the A horizon ranged from 7 - 10 cm on the upper slope and 12 - 18 cm on the lower slope position. Solum depth was 30 - 40 cm at the upper slope position and 70 - 80 cm at the lower slope position.

Climatic data

Rainfall, air temperature and relative humidity were measured at the upper slope position of the experimental site. Two white porcelain spherical atmometers were placed at each slope position to measure potential evaporation. The atmometric readings were collected weekly. Atmometers were maintained 5 - 10 cm above the canopy height at later stages.

A remote recording rain gage (model P-501, Weather Measure Corp., Calif. 95841, USA.) with an event recorder (model P-521, Weather Measure Corp., Calif. 95841, USA.) was placed at the site. The event recorder charts were replaced weekly. The daily air temperature and relative humidity were recorded in a recording type thermohygrograph (type 252, Wilh. Lambrecht KG Gottingen) which was also set up for weekly recording.

Soil moisture measurements:

Soil moisture levels were determined weekly at each slope position at 10, 20,40, 60, 80 and 100 cm depths with a neutron probe and at 0 - 10 cm gravimetrically at two positions 5m apart at each slope position.

Root distribution measurements :

At the seedling stage, the whole root system was carefully removed and washed. Root length was measured with Ag Vision monochrome system (Decagon Devices Inc., Pullman, WA 99163, USA) after staining. Root sampling was done at each location once every two weeks.

Root distribution was studied by adopting the trench - profile method (Bohm, 1979) A trench was made approximately 1m wide, across 6 rows of mustard. The vertical wall across the rows was smoothed with a metal dust pan and a brush. Roots were exposed by removing a soil layer of about 1 cm thick from the working face by spraying water. A polythene sheet with previously marked grids of 10 cm was placed on the working face and roots were marked with dots on the polythene sheet. After sampling, the working face was covered with a piece of cloth and the trench was refilled with the same soil. The same trench was dug again and used for consecutive sampling, each time removing a soil layer of about 5 - 10 cm along the rows.

Results and Discussion :

Climatic Data

Rain Fall precipitation and potential evapotranspiration

Total precipitation for the 12 week period of crop growth was 67 mm with 20 rainy days. The cumulative atmospheric evaporation during the 12 week field period as estimated by water loss per atmometer was 2641 and 2384 g per atmometer at the upper and lower slope positions, respectively. A 10% lower potential evaporation was estimated for the lower slope as compared to the upper slope position.

Air temperature and Relative Humidity

The maximum temperature of 39^{o}C was observed in the field on 11 DAS and 80 DAS. The minimum temperature recorded was -2^{o}C on the date of swathing (87 DAS). The recorded RH% values ranged from a minimum of 31 to maximum of 90.

Soil moisture variation

Figure 1 shows the soil moisture variation at selected depths at upper and lower slopes. Highest soil moisture status was observed at the beginning of the season for upper slope position and only up to depth of 60 cm at lower slope position. The maximum water content for the depth below 80 cm at lower slope was reached at about 7 weeks. This depth was depleted to about 35% of the available soil moisture during 8 - 9 weeks and again increased moisture status afterwards to the previous level.

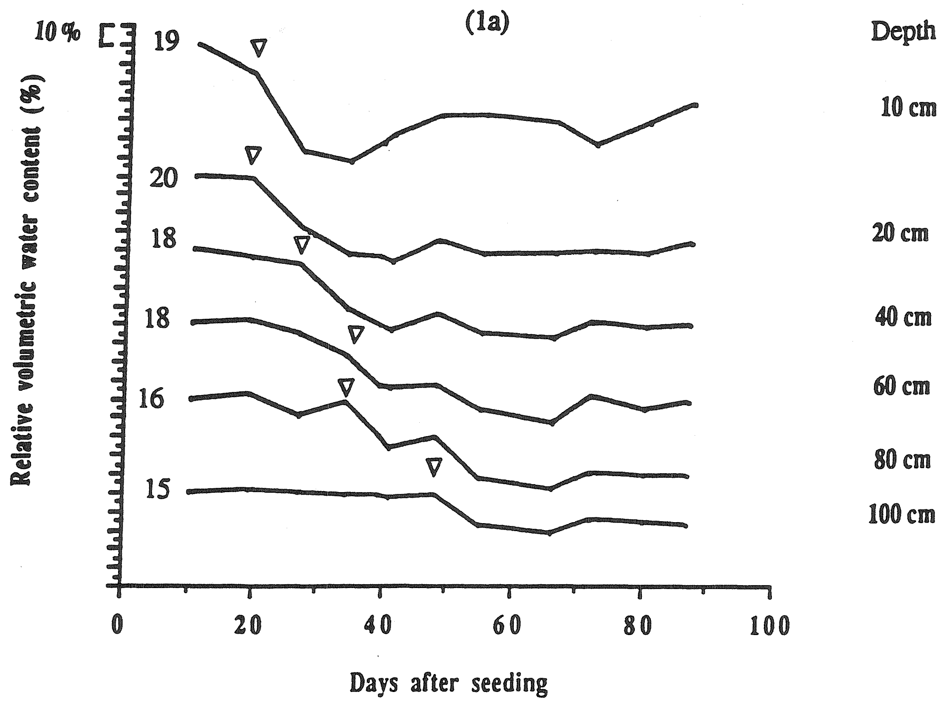
Root growth measurements :

Root length was found to be 32 and 60 cm at 3 weeks after sowing (WAS) and 54 and 91 cm at 4 WAS for upper and lower slope positions respectively. More than 80 % of the roots were found in the upper 60 cm and 50 cm of the profile at upper slope and lower slope positions, respectively. Only about 4% of the roots were found below 100 cm on the upper slope and 90 cm on the lower slope.

Maximum root and water extraction depths

Roots were found at depths of 125 , 143 and 150 cm at the upper slope position at 8, 10 and 12 weeks respectively. For the lower slope position root depths were 90, 117 and 120 cm for the same sampling periods.The maximum water depletion depths were estimated according to McGowan (1974). Maximum rooting depth for mustard reached 150 cm at the upper slope position. At the early growth stages, the effective rooting depths were found below the rooting depths which may be due to upward migration of soil moisture. At the upper slope position the effective rooting depth reached 120 cm but was above the maximum rooting depth (Figure 2). At the lower slope position the effective rooting depth reached 100 cm depth only for about a 2 week period and depleted the soil to about 35% of the available moisture. For the rest of the growing season the water depletion depth was around 60 - 80 cm at the lower slope position.

Figure 1. The change in soil water content at selected depths measured during the crop growth at the upper slope position (1a) and at the lower slope position (1b). The initial water content of each layer is shown at the start of each curve and the arrow represents the beginning of water extraction by roots.



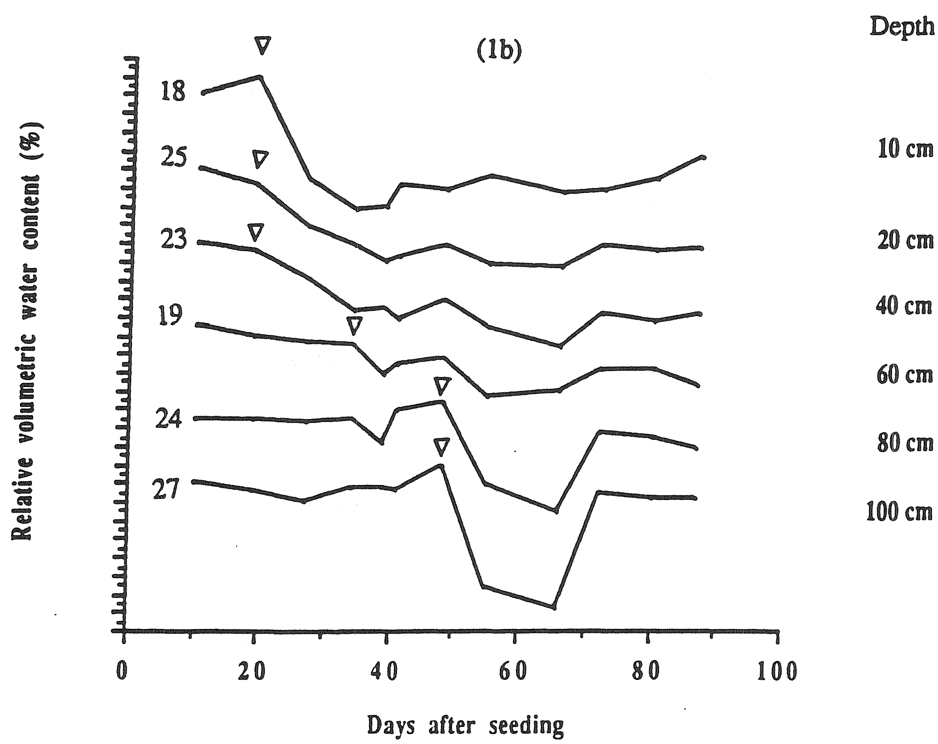
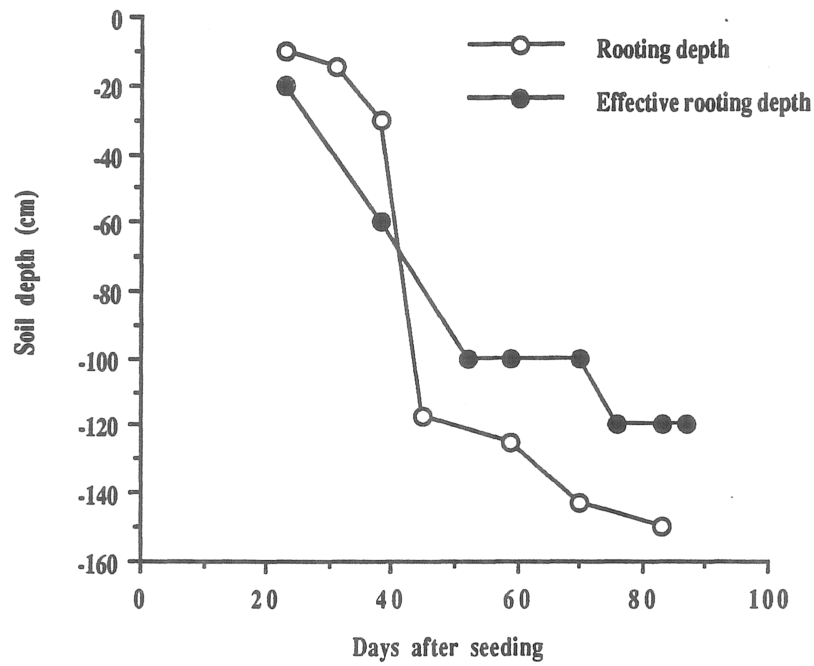
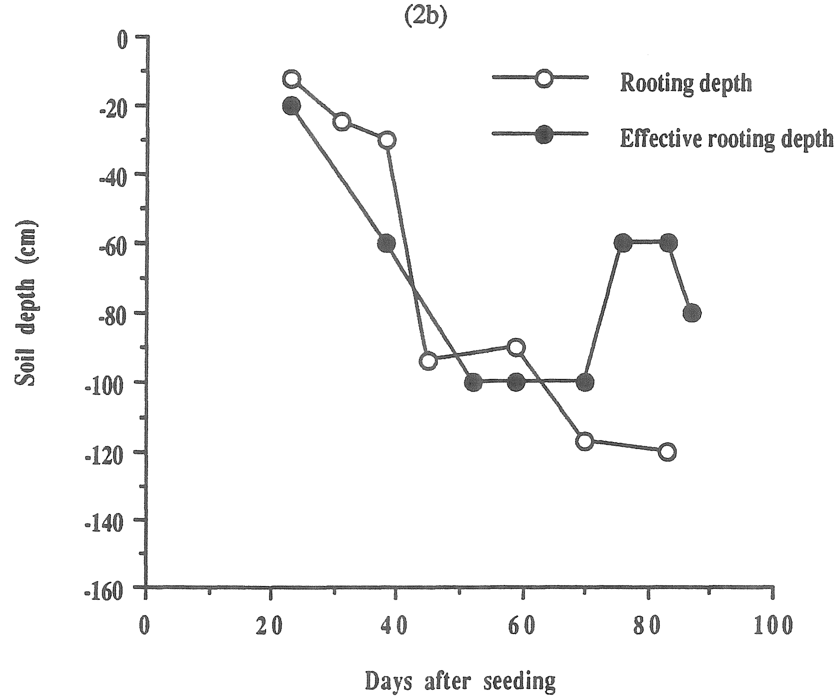


Figure 2. A comparison of effective rooting depth estimated from the neutron probe (●) with measured rooting depth (○) at upper slope position (2a) and lower slope position (2b).

(2a)



(2b)



Conclusions :

The following inferences can be made from the available information :

- Mustard roots grow very deep in sandy loam soil. But the effective rooting depth was shallower than the rooting depth.
- The water depletion depths were found below the rooting depths at the early growth stages which may be due to upward migration of soil moisture.
- Both root and water depletion depths were deeper at upper slope compared to lower slope position in the catena.
- Roots were found below the water depletion depth but but were in very low densities.

References :

Allmaras, R. R., W. W. Nelson, and W. B. Voorhees. 1975. Soybean and corn rooting in southwestern Minnesota : II. Root distribution and related water inflow. Soil Sci. Soc. Am. Proc. 39:771-777.

Bohm, W. 1979. Methods of studying root systems. Ecological Studies 33. Spring-Verlag, Berlin. p 48 - 60.

Durrant, M. J., B. J. G. Love, A. B. Messem, and A. P. Draycott. 1973. Growth of crop roots in relation to soil moisture extraction. Ann. Appl. Biol. 74: 387-394.

Entz, M. H., K. G. Gross, and D. B. Fowler. 1992. Root growth and soil-water extraction by winter and spring wheat. Can. J. Plant Sci. 72:1109-1120.

Gardner, F. P. 1985. Physiology of crop plants. The Iowa State Univ. Press, Ames,Iowa. pp.77-270.

Gregory, P. J., M. McGowan, and P. V. Biscoe. 1978. Water relations of winter wheat 2. Soil water relations. J. Agric. Sci.,Camb. 91:103-116.

Hurd, E. A. 1968. Growth of roots of seven varieties of spring wheat at high and low moisture levels. Agron J. 60: 201-205.

McGowan, M. 1974. Depths of water extraction by roots. Application to soil-water balance studies. *In* Isotope and radiation Techniques in Soil Physics and Irrigation Studies. pp.435-445. Vienna: I.A.E.A.

Passioura, J. B. 1981. Water collection by roots, *In* L. G. Paleg and D. Aspinall (eds) Physiology and biochemistry of drought resistance in plants. p39-53.

Protopapas, A. L., and R. L. Bras. 1987. A model for water uptake and development of root system. Soil Sci. 144:352-366.

Stone, L. R., I. D. Teare, C. D. Nickell, and W. C. Mayaki. 1976. Soybean root development and soil water depletion. Agron. J. 68:677-680.