International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 1005-1008

Received: 09-05-2018
Accepted: 15-06-2018

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Studies on effect of season, radial distance and depth on root distribution pattern of Kinnow mandarin

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Abstract
The present investigation on root distribution was carried out at Horticultural Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during March, 2017 to October, 2017. The experiment was conducted on 8 years old trees of Kinnow mandarin (*Citrus reticulata*) on rough lemon rootstocks laid out in Randomized Block Design with two seasons (spring and autumn), three radial distance (0-60 cm, 60-120 cm, 120-180 cm) and three depths (0-20 cm, 20-40 cm, 40-60 cm). The study of root distribution pattern was carried for spring season and its interactions with different radial distance and soil depths. Similarly with autumn season the interactions effect with different radial distance and soil depths were studied. Interactions effect among different radial distance and soil depth. The spring season gave significantly higher dry weight of fibrous and thin roots. Most of the fibrous roots were present at 0-60 cm radial distance and 0-20 cm soil depth in spring season. Therefore the application of proper amount of fertilizers and irrigation water should be applied in this zone for fairly better absorption by the tree roots.

Keywords: Kinnow mandarin, season, radial distance, depth, fibrous roots, thin roots, rough lemon

Introduction
Kinnow mandarin (*Citrus reticulata)* is an evergreen fruit plant and well adopted to sub-tropical climatic conditions. The root distribution studies are one of the most important aspects of fruit trees, which plays a vital role in linking the uptake of nutrients and water from the root zone. The root distribution studies is affected by a numerous factors such as age of tree, season, rootstocks, variety of scion, soil texture, fertility, tillage, growing conditions of tree and various other cultural practices (Singh and Misra) [10]. The study of root distribution of a species in a location cannot be applied to the same species in a different location. Therefore, there is a very immediate need for studying the root distribution studies for different agro-climatic conditions. The method of direct root excavation gives clear picture of the naturally existing entire root system of the tree. In direct root excavation method some of the roots are lost during working with the larger soil volume. However, no information is available on root distribution pattern of Kinnow mandarin grafted on rough lemon rootstock under *tarai* conditions of Pantnagar. Therefore, there is a need to study the root distribution pattern of Kinnow mandarin.

Materials and Method
The present investigation was undertaken during the year 2017 in the Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand). The experiment was conducted on 8 year old uniform and healthy trees of Kinnow mandarin cultivar budded on rough lemon rootstock. The trees were planted at a distance of 8 m in the square system. The use of three Factorial Randomized Block Design was done for laying down the experiment with two seasons (spring and autumn), three radial distance (0-60 cm, 60-120 cm, 120-180 cm) and three depths (0-20 cm, 20-40 cm, 40-60 cm) combinations thus formed. The total Eighteen treatment combinations thus formed were replicated twice. In each tree, a circle of 180 cm radius was drawn around the tree trunk and $1/8^{th}$ portion of the area was marked in the south-east direction and was then excavated, Figure-1. This $1/8^{th}$ portion was further divided into three sectors, i.e., at 0-60 cm (D_1), 60-120 cm (D_2) and 120-180 cm (D_3) distance from the tree trunk.

Each sector was excavated at three different depths of 0-20 cm (d_1), 20-40 cm (d_2) and 40-60 cm (d_3). The roots were collected from each sector separately and washed with water on a wiremesh. The fibrous roots obtained were graded into four categories, on the basis of their diameter, *viz.*(i) < 0.2 cm, (ii) >0.2 to 0.5 cm, (iii) > 0.5 cm to 1.5 cm and (iv) > 1.5 cm. These roots were designated as fibrous, thin, medium and thick roots (Aiyappa and Srivastava, 1). After grading of roots in the above four categories, the roots were then surface dried under fan. The dried roots were then put in the paper bags and kept in an oven at 60±1ºC for 72 hours for drying and then the constant dry weight of roots were recorded. The amount of roots were then expressed as grams of dry roots per cubic metre of volume. The data obtained in the experiment was subjected to analysis of variance in three factor randomized block design. The three factors taken during the experiment were season, radial distance and depth and interpretation of results were made on the basis of 'f-test'. For comparing treatment means the critical differences at 0.05 level of probability was calculated.

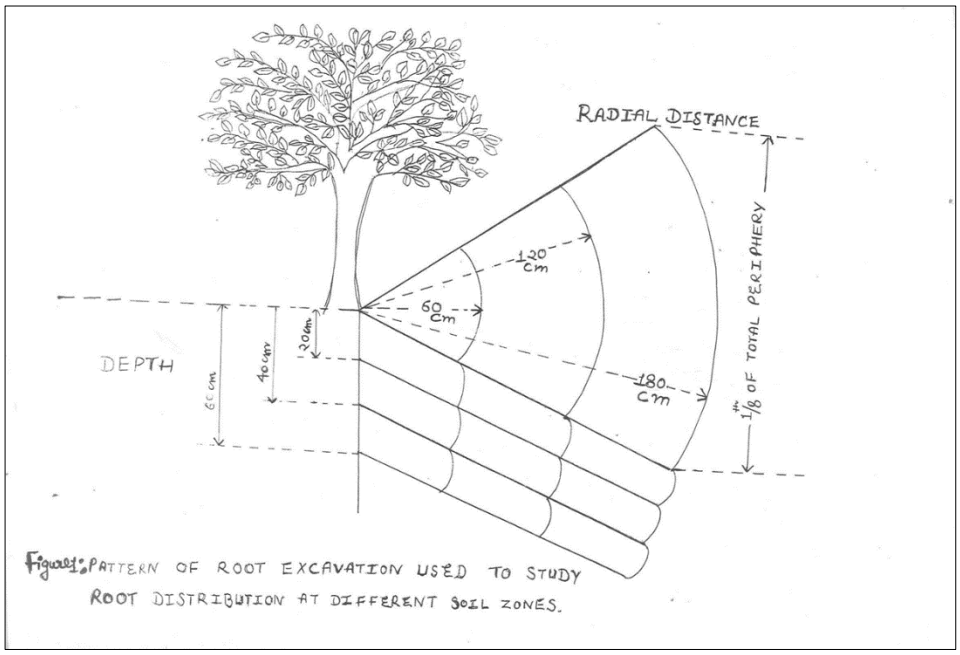

Figure 1: PATTERN OF ROOT EXCAVATION USED TO STUDY ROOT DISTRIBUTION AT DIFFERENT SOIL ZONES.

Results and Discussion

Effect of season on dry weight of fibrous, thin, medium and thick roots

The effect of seasons on dry weight of fibrous, thin, medium and thick roots indicates significant variation among the treatments. The spring season produced maximum dry weight of fibrous roots which was then followed by autumn season, which may be due to proper water availability and soil temperature. The maximum dry weight of thin roots was produced during spring season. Singh and Misra [10] found that spring season gave significantly higher dry weight of active roots as compared to autumn season. The higher dry weight of fibrous and thin roots in spring season might be due to the favourable soil aeration, moisture and temperature during spring season. Autumn season was observed with maximum dry weight of medium roots. The higher dry weight of thick roots in autumn season might be due to the shedding of fibrous roots. Higher water table might be the reason of more amount of thin roots during rainy season. Effect of different seasons on feeder root distribution pattern was reported in Kinnow mandarin and Pearl tangelo (Chandra and Yamdagini, [3] Coorg mandarin on rough melon rootstock (Iyenger and Keshava, [4], guava (Kotur *et al.*, Purohit and Mukherjee [5, 9].

Table 1: Effect of season, radial distance and depth on dry weight of fibrous, thin, medium and thick roots.

Treatments	Dry weight(g)			
	Fibrous roots	**Thin roots**	**Medium roots**	**Thick roots**
Seasons				
Spring	102.18(9.54)	181.89(12.44)	342.82(16.90)	500.91(17.72)
Autumn	74.73(8.07)	167.80(11.53)	360.00(17.17)	864.79(22.08)
C.D. at 5%	(0.21)	(0.19)	(0.17)	(1.25)
Radial distance (cm)				
0-60	125.55(10.71)	273.87(15.72)	672.99(15.72)	1,602.14(37.10)
60-120	94.41(9.35)	190.96(12.94)	316.57(12.94)	380.11(15.79)
120-180	45.41(6.36)	59.69(7.32)	64.68(7.32)	66.31(6.820)
C.D. at 5%	(0.26)	(0.23)	(0.29)	(1.54)
Depth (cm)				
0-20	153.64(12.20)	330.41(17.50)	336.92(17.50)	427.29(12.52)
20-40	79.56(8.64)	134.28(11.04)	477.79(11.04)	1330.41(31.33)
40-60	32.17(5.58)	59.82(7.44)	239.52(7.44)	290.86(15.86)
C.D. at 5%	(0.26)	(0.23)	(0.29)	(1.54)

Figures in parentheses indicate square root transformed values.

Table 2: Effect of interactions (a) season × radial distance (b) season × depth (c) radial distance × depth on dry weight of fibrous, thin, medium and thick roots

(a)	Seasons	Radial distances (cm)											
	Fibrous roots			Thin roots			Medium roots			Thick roots			
	$D_{1(0-60)}$	$D_{2(60-120)}$	$D_{3(120-180)}$	$D_{1(0-60)}$	$D_{2(60-120)}$	$D_{3(120-180)}$	$D_{1(0-60)}$	$D_{2(60-120)}$	$D_{3(120-180)}$	$D_{1(0-60)}$	$D_{2(60-120)}$	$D_{3(120-180)}$	
Spring	144.27 (11.51)	110.36 (10.14)	51.93 (6.99)	281.62 (16.02)	196.82 (13.52)	67.22 (7.83)	649.84 (25.212)	309.89 (17.35)	68.72 (8.15)	1,097.84 (31.64)	340.980 (14.90)	63.91 (6.62)	
Autumn	106.83(9.91)	78.47(8.57)	38.892(5.73)	266.11(15.43)	185.13(12.36)	52.16(6.81)	696.14(26.06)	323.25(17.76)	60.63(7.78)	2,106.44 (42.56)	419.24(16.68)	68.71(7.01)	
CD at 5%		NS		(0.19)			(0.29)			(2.17)			
(b)	Seasons				Depths (cm)								
		Fibrous roots		Thin roots			Medium roots			Thick roots			
	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	
Spring	173.39 (12.93)	95.03 (9.56)	38.13 (6.14)	325.42 (17.42)	147.379 (11.697)	72.86 (8.25)	330.27 (17.35)	467.64 (19.73)	230.54 (13.64)	342.00 (11.32)	916.80 (27.28)	243.93 (14.56)	
Autumn	133.88 (11.47)	64.10 (7.72)	26.21 (5.02)	335.41 (17.58)	121.180 (10.386)	46.81 (6.62)	343.57 (17.51)	487.94 (19.69)	248.51 (14.38)	512.58 (13.72)	1,744.01 (35.37)	337.80 (17.17)	
CD at 5%		(0.36)			(0.33)			(0.29)			(2.173)		
(c)	Radial distances (cm)				Depths (cm)								
	Fibrous roots			Thin roots			Medium roots			Thick roots			
	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	
$D_{1(0-60)}$	215.58 (14.64)	117.40 (10.86)	43.66 (6.62)	508.32 (22.56)	213.60 (14.64)	99.68 (9.96)	540.26 (23.25)	976.15 (31.24)	502.56 (22.43)	1,281.86 (35.550)	3,044.05 (53.97)	480.51 (21.78)	
$D_{2(60-120)}$	157.02 (12.52)	88.57 (9.33)	37.64 (6.21)	365.72 (19.10)	149.09 (12.09)	58.11 (7.62)	380.01 (19.50)	392.10 (19.82)	177.59 (13.35)	0.00 (1.00)	807.17 (28.16)	333.16 (18.20)	
$D_{3(120-180)}$	88.31 (9.44)	32.71 (5.73)	15.21 (3.91)	117.21 (10.84)	40.14 (6.39)	21.71 (4.73)	90.49 (9.54)	65.12 (8.08)	38.42 (6.24)	0.00 (1.00)	140.00 (11.85)	58.93 (7.61)	
CD at 5%	(0.45)				(0.41)			(0.35)			(2.66)		

Table 3: Effect of interactions (seasons × radial distances × depths) on dry weight of fibrous, thin, medium and thick roots (g).

Seasons	Fibrous roots									Thin roots								
	$D_{1(0-60)}$			$D_{2(60-120)}$			$D_{3(120-180)}$			$D_{1(0-60)}$				$D_{2(60-120)}$			$D_{3(120-180)}$	
	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$
Spring	254.28 (15.96)	124.45 (11.18)	54.05 (7.40)	175.14 (13.27)	117.58 (10.88)	38.36 (6.27)	90.76 (9.57)	43.05 (6.63)	21.98 (4.77)	525.6 (22.94)	199.81 (14.17)	119.43 (10.94)	128.32 (11.35)	46.67 (6.90)	26.67 (5.25)	128.31 (11.35)	46.67 (6.90)	26.67 (5.25)
Autumn	176.88 (13.33)	110.34 (10.55)	33.28 (5.84)	138.90 (11.78)	59.58 (7.77)	36.93 (6.16)	85.87 (9.32)	22.38 (4.83)	8.43 (3.06)	322.2 (17.98)	195.67 (14.02)	72.47 (8.56)	491.01 (22.18)	227.40 (15.11)	79.93 (8.99)	106.10 (10.34)	33.61 (5.88)	16.76 (4.20)
CD at 5%	(0.63)									(0.58)								
	Medium roots									Thick roots								
	$D_{1(0-60)}$			$D_{2(60-120)}$			$D_{3(120-180)}$			$D_{1(0-60)}$				$D_{2(60-120)}$			$D_{3(120-180)}$	
	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$	$d_{1(0-20)}$	$d_{2(20-40)}$	$d_{3(40-60)}$
Spring	525.08 (22.92)	932.97 (30.55)	491.47 (22.19)	367.70 (19.18)	393.53 (19.85)	168.433 (13.011)	98.02 (9.94)	76.43 (8.97)	31.71 (5.71)	1,025.99 (31.94)	1,878.10 (43.30)	389.43 (19.67)	0.00 (1.00)	730.31 (26.62)	292.63 (17.09)	0.00 (1.00)	142.00 (11.93)	49.73 (6.94)
Autumn	555.43 (23.58)	1,019.33 (31.93)	513.66 (22.69)	392.31 (19.83)	390.67 (19.79)	186.76 (13.69)	82.94 (9.13	53.82 (7.38)	45.12 (6.77)	1,537.73 (39.15)	4,210.00 (64.64	571.58 (23.90	0.00 (1.00)	884.03 (29.71)	373.68 (19.32)	0.00 (1.00)	138.00 (11.77)	68.12 (8.27)
CD at 5%					(0.50)									(3.76)				

Effect of radial distance on dry weight of fibrous, thin, medium and thick roots

The effect of radial distance on various categories of roots i.e., fibrous, thin, medium and thick roots were found to be significant. The significant higher dry weight of fibrous, thin, medium and thick roots were observed at radial distance of 0-60 cm from the tree trunk. The maximum dry weight of fibrous roots was observed at 0-60 cm away from the tree trunk in lemon budded on trifoliate orange rootstock, (Misra *et al.*, [8]. Increase in the radial distance significantly reduced the dry weight of all categories of roots. Singh and Misra [10] in *bael*, and Misra and Jaiswal [7] in *karonda* reported declining pattern of dry weight of roots with increase in radial distance from tree trunk.

Effect of soil depth on dry weight of fibrous, thin, medium and thick roots

The significant effect of soil depth was found on various categories of roots. The dry weight of fibrous roots were maximum at 0-20 cm and then at 20-40 cm depth. The amount of fibrous roots were minimum for 40-60 cm of soil depth. In karonda (*Carrisa carandas* L.) maximum dry weight of fibrous roots was recorded at 0-20 cm depth from the soil surface which decreased with increasing soil depth (Misra and Jaiswal, [7]. At 0-30 cm soil depth, maximum dry weight of fibrous roots in litchi was found and with increasing the soil depth the dry weight of fibrous roots decreased (Agnihotri *et al.*, [2]. The maximum dry weight of thin roots was noted with 20-40 cm depth which was significantly higher then 0-20 cm and 20-40 cm depth. The maximum amount of fibrous, medium and thick roots was recorded at 0-20 cm soil depth. The study on root system of litchi reported that the maximum dry weight of active roots was observed at 0-30 cm depth from the soil surface which significantly decreased with increased depth (Misra and Dabral, [6].

Effect of interactions, season × radial distance, season × soil depth, radial distance × soil depth and season × radial distance × soil depth on dry weight of fibrous, thin, medium and thick roots

The interactions of season × radial distance, season × soil depth, radial distance × soil depth and season × radial distance × soil depth on dry weight of fibrous, thin, medium and thick roots was found to be significant. The interaction between season × radial distance reveals that the spring season × 0-60 cm radial distance gave significantly higher dry weight of fibrous roots. The dry weight of thin roots were highest for autumn season × 0-20 cm soil depth, while autumn season × 0-60 cm radial distance observed with significantly higher dry weight of medium and thick roots.

The interactions between season × soil depth indicates that the maximum dry weight of fibrous roots and thin roots was found during spring season × 0-20 cm soil depth. The maximum dry weight of medium roots were found during autumn season × 0-20 cm soil depth, while thick roots were maximum during autumn season × 20-40 cm soil depth.

Among the interactions between radial distance × soil depth, maximum dry weight of fibrous roots and thin roots was present at 0-20 cm soil depth × 0-60 cm radial distance. The interaction effect between radial distance × soil depth was found that 0-60 cm radial distance × 20-40 cm soil depth gave maximum dry weight of medium roots. For dry weight of thick roots the maximum amount was found at a radial distance of 0-60 cm × 20-40 cm soil depth.

Among the interactions between season × radial distance × soil depth maximum amount of dry weight of fibrous roots reported at spring season × 0-60 cm radial distance × 0-20 cm soil depth. The maximum thin root reported at spring season × 0-60 cm radial distance × 0-20 cm depth. The amount of maximum dry weight of medium roots was found in autumn season × 0-60 cm radial distance × 20-40 cm soil depth. The autumn season × 0-60 cm radial distance × 20-40 cm soil depth was observed with highest dry weight of thick roots.

On the basis of the above experimental findings, it can be summarized that the interactions between seasons, radial distances and soil depths in all types of roots were found to be significant. The spring season gave significantly higher dry weight of fibrous roots and thin roots, while autumn season gave significantly higher dry weight of medium and thick roots. Most of the fibrous roots were present at 0-60 cm radial distance and 0-20 cm soil depth. Therefore fertilizers and irrigation water may be applied in this zone irrespective of seasons for better utilization of these resources by the tree roots.

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