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Fibrous Root Distribution in Blood Red Sweet Orange Trees under Semi- arid Irrigated Ecosystem

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Abstract

Fibrous root distribution pattern of mature trees of sweet orange cultivar Blood Red budded on rough lemon with her cleoptera and troyer citrange rootstocks were studied by root excavation method. The roots excavated from four radial distances i.e.0-75,75-150,150-225 and 225-300 cm from the tree trunk and three depths i.e.0-15, 15-30 and 30-60 cm from the ground level indicated that fibrous root dry weight density and proportion of dry weight differed significantly at various depths and radial distances. Cleoptera has more feeder roots as compared to rough lemon and troyer. Feeder root dry weight density and dry weight proportion was almost the same between 0-15 & 15-30 cm depth and at deeper horizon there was significant decrease in all the root stocks. Approximately 70% of the total feeder roots in all rootstocks were within 0-30 cm depth i.e. intensive vertical development. The highest feeder root dry weight density was recorded at 0-75cm radial distance after that there was a sharp decrease. Troyer citrange, cleoptera and rough lemon contain about 65, 61 and 50% feeder roots up to 150 cm radial distance from the trunk. Hence, feeder roots, in troyer citrange and cleoptera may be exemplified as intensive lateral development. Rough lemon bears extensive lateral development as it has substantial amount of feeder roots at 150-225cm radial distance.

Highlights

- Troyer citrange showed intensive lateral and somewhat extensive vertical development of fibrous roots
- Cleoptera and rough lemon showed extensive lateral and intensive vertical development of fibrous roots

Keywords: Sweet orange, feeder roots, rootstocks, depth, radial distance

Citrus is one of the most important fruit crop in India and among citrus, sweet orange may have its important place in earning the foreign exchange. Citrus production depends not only upon soil, climate and high density planting but the root stocks also play an important role as different rootstocks have different intensities of root proliferation and penetration. Moreover, roots are the principal organ for absorption of nutrients and water from soil. So, increasing the density of fibrous root within a crop root system increases the amount of water and nutrients available to the crop (Tinker and Nye, 2000).The rootstock in turn can be influenced by the scion and soil environment. Performance of rootstock in a certain environment is related to total volume, configuration, lateral distribution and depth of the root system (Cintra *et al.*, 2000). The root distribution pattern of different trees varies from season to season, region to region and from one root stock – scion combination to another (Singh *et al*., 2012 in guava, Dalal and Thakur, 2011 in citrus and Agnihotri *et al.*, 2009 in litchi). Mikhail and El-Zfhoui (1979) found that 79% of the total fibrous root of Valencia orange occurred in the first 60 cm of soil depth on sandy soil, whereas, clay soil contained 94% in the same depth. Similarly, different root stocks have different root system and their distribution (Misra *et al*., 2003; Neves *et al*., 2004 and Morgan *et al*., 2007). These differences in rooting pattern among rootstocks and soil environments are more likely to reflect the adaptation of plants to a given environment. Hence, a clear understanding of root system is important to deal best management practices such as irrigation and nutrients application and fixing the geometry in a particular ecosystem. Keeping in view the above facts, the present investigation was carried out with the objectives to determine the root distribution of mature Blood Red orange budded on three rootstocks under semi-arid irrigated ecosystem.

Materials and Methods

Experimental site and soil characteristics

The experiment was conducted at the experimental orchard of the CCS Haryana Agricultural University, Hisar, during spring season. The average rainfall of the area is 450 mm/ year. However most of the rainfall is received during Southwest monsoon season (July to mid September). The mean maximum temperature remain 40-45^{0}C during June with hot winds and minimum temperature 4-5^{0}C during January. The soil samples collected at the depth of 0-30 cm were analyzed for their physical and chemical properties. The soil type was loamy sand, bulk density 1.5g/cc with moisture holding capacity of 40-45 %, moisture at field capacity 25-28%. The pH of the site was 8.32 with EC 0.2dsm^{-1} and calcium carbonate 5-10 %.

Lay out and sample collection

Mature Blood Red orange trees budded on three rootstocks i.e. rough lemon (*Citrus jambhiri* Lush), cleoptera (*Citrus reshni*) and Troyer Citrange (*Poncirous trifoliate* x *Citrus sinensis* Osbeck) and spaced at 6×6 meters were selected for the study. All the three sets of five randomly selected mature trees under uniform cultural practices in a randomized block design were examined for their root distribution. In each plant a circle with a radius of three meter from tree trunk was marked. This radius was further divided into four segments with 0-75, 75-150,150-225 and 225-300cm radius. The circle circumference was further divided into eight parts and 1/8th portion was excavated at three depths viz. 0-15, 15-30 and 30-60cm. Roots of 15 plants were excavated with a jet of water at a pressure of 10-15 PST. The plants were exposed to a radial distance of 3 meter from the trunk, first up to the depth of 15cm. from ground surface and roots were painted with red color. The roots were further excavated to a depth of 30cm i.e. between 15-30cm and exposed roots were painted with yellow color. The roots were further excavated up to a depth of 60cm i.e. between 30-60cm and these roots were kept as such to distinguish from other roots. After the entire root system was exposed, the roots were collected from each segment of depth and radial distance separately and washed. The root diameter was measured with the help of vernier caliper and roots having diameter < 2mm were categorized as fibrous roots.

Data collection

The fibrous root dry weight of each segment was measured with the help of top pan balance after oven drying the roots at 70^{0}C till the constant weight. Feeder root dry weight density (FRDWD) and feeder root dry weight proportion (%) was estimated for soil volume represented by each sample of radial distance and depth increment for each of the 15 orange trees. The surface area of the ring of radial distance 0-75cm (A) was determined by calculating the area of a circle with radius of 75cm. The area of ring between radial distances 75-150cm (B) was equal to area of a circle with a radius of 150cm minus area of ring A. The area of ring 150-225cm radial distance (C) was equal to area of a circle with a radius of 225cm minus area of ring B. Similarly area of ring 225-300cm radial distance (D) was equal to the area of a circle with a radius of 300cm minus area of ring C. The volume of soil used to determine the estimated feeder root dry weight density (FRDWD) at each sampling location was the product of the area of each ring determined by the sampling distance and soil depth (0-15, 15-30 and 30-60cm) and then divided by 8 because only 1/8th part of each ring was excavated. Feeder root dry weight density (FRDWD) was determined by dividing the sample dry weight for each sampling location by their respective sample soil volume and expressed as g feet$^{-3.}$The dry weight percentage at various depth zones and radial distances from tree trunk was determined on the basis of total dry weight irrespective of radial distance and depth, respectively.

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Statistical analysis

The experiment was laid out in randomized block design with three sets and five replications. The fibrous root dry weight density (FRDWD) and proportion of dry weight of the three rootstocks at various depths and radial distances from the trunk were analyzed as per standard procedure (Panse and Sukhatme, 1985)

Results and Discussion

Feeder root distribution at different depths

Feeder root dry weight density (FRDWD) and proportion of dry weight at different depths and radial distances differed significantly in all the root stocks (Table-1). Feeder root dry weight density did not differ significantly between 0-15 and 15-30 cm depth in all the three root stocks. However at the deeper horizon.i.e.30-60 cm depth there was a sharp decrease and the maximum FRDWD's 3.89,5.83 and 3.29g feet^{-3} soil volume was observed at upper soil layer (0-15cm) closely followed by sub-surface layer (15-30cm) depth, 3.40,5.50 and 3.30g feet^{-3} soil volume and minimum 1.61,2.48 and 1.43g feet^{-3} at 30-60 cm depth in rough lemon, cleoptera and troyer citrange respectively. The proportion of feeder root dry weight was also found maximum on upper soil layer i.e.0-15 cm depth. Where rough lemon and cleoptera were used as root stock, there was a significant decrease in the root dry weight percentage with every increase in depth, while on troyer citrange the same proportion of root dry weight was noticed at 0-15 and 15-30 cm depth. In all the root stock approximately 70% of the feeder roots were concentrated up to 30 cm depths. These results are in agreement with those of (Dalal and Thakur, 2011 and Singh *et al.*, 2008) who concluded that citrus is basically a surface feeder crop and also reported that root density was greater at surface sample and decreased with the depth in Pineapple and Blood Red oranges budded over rough lemon cleoptera and troyer citrange. Carrizo citrange has intensive type root system with few fibrous roots below 0.7meter in Hamlin (Morgan *et al.*, 2007). Sharma and Chauhan (2005) also found nearly all fibrous roots above 50 cm depth with very few roots within 75-100 cm in apple.

Table 1: Feeder root dry weight density (FRDWD) and proportions on dry weight basis at various depths and radial distances in sweet orange cv. Blood Red.

Treatment	Rough lemon		Cleoptera		Troyer citrange	
	FRDWD (g feet^{-3} soil)	Root dry wt. (%)	FRDWD (g feet^{-3}soil)	Root dry Wt. (%)	FRDWD (g feet^{-3} soil)	Root dry wt. (%)
Depth (cm)						
0-15	3.89	36.62	5.83	35.52	3.28	34.46
15-30	3.40	31.97	5.50	33.68	3.30	34.59
30-60	1.61	31.21	2.48	30.47	1.43	30.38
C.D. at 5%	0.51	0.91	0.65	1.16	0.45	1.08
Radial distance (cm)						
0-75	10.74	24.73	17.98	27.44	14.87	37.34
75-150	3.58	24.80	6.95	31.89	3.68	27.72
150-225	2.69	30.96	3.08	23.82	1.65	20.85
225-300	0.95	17.62	1.32	16.66	0.68	14.02
C.D. at 5%	1.45	3.20	1.78	3.33	1.63	4.14

Table 2: Interaction of radial distances and depths on Feeder root dry weight density (FRDWD) in sweet orange cv. Blood Red

Radial distances/ Depths (cm)	Rough lemon			Cleoptera			Troyer citrange		
	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
0-75	17.11	11.65	7.23	33.37	19.08	7.70	16.81	17.77	8.82
75-150	5.74	4.40	2.13	8.51	10.92	6.35	5.08	7.06	1.30
150-225	3.77	4.42	1.31	4.05	5.31	2.98	3.07	1.52	1.04
225-300	1.36	1.11	0.96	2.06	1.50	1.71	0.72	0.83	0.77
C.D. at 5%	0.15	15.30	30.60						

Feeder root distribution at different radial distances

Feeder root dry weight density (10.74, 17.98 and 14.87g feet^{-3}) soil volume was most concentrated close to the tree trunk i.e. 0-75 cm radial distance in rough lemon, cleoptera and troyer citrange, respectively. After every 75 cm increment in the radial distance there was decrease in the FRDWD. In rough lemon root stock FRDWD was at par between 75-150 and 150-225 cm. radial distance and further increment in radial distance results in significant decrease in FRDWD, whereas, in cleoptera and troyer citrange there was a significant decrease in FRDWD between 75-150 and 150-225 cm radial distance and further increment in radial distance results in non-significant decrease. The intensity of decrease was approximately 75, 61 and 66 % from 0-75 to 75-150 cm in troyer citrange, cleoptera and rough lemon, respectively. After that cleoptera and troyer citrange showed the same intensity of decrease i.e. 56 % at every increment of 75 cm radial distance, whereas, rough lemon showed only 25 % decrease from 75-150 to 150-225 cm radial distance. These results are in conformity with those of (Dalal and Thakur, 2011 and Singh *et al,* 2008) in sweet oranges.

The maximum proportion of the feeder roots dry weight, 37.34, 31.89 and 30.96% at 0-75,75-150 and 150-225 cm radial distance was observed in troyer citrange, cleoptera and rough lemon, respectively. The feeder root dry weight percentage was closer to the tree trunk i.e. 0-75 cm radial distance in troyer citrange, then there was significant decrease at every increment of 75 cm and cleoptera showed significant increase in dry weight percentage at 75-150 cm over 0-75 cm radial distance and then significant decrease. Whereas, in rough lemon it was at par between 0-75 and 75-150 cm radial distance and there after significant increase at 150-225 cm radial distance. The proportions of feeder roots were 65.06, 59.33 and 49.53% up to 150 cm radial distance in troyer citrange, cleoptera and rough lemon, respectively. Hence, rough lemon bears a substantial amount of feeder roots at 150-225 cm radial distance as compared to cleoptera and troyer. Similarly, (Dalal and Thakur, 2011 and Singh *et al,* 2008) earlier reported that trees on rough lemon and cleoptera roots stocks are typical of citrus tree with extensive roots structure of fibrous roots. Morgan (2007) reported that carrizo citrange root stock has less lateral development in Hamlin. In citrus fibrous roots dry weight density ranged between 300 to 1200 g/m^{-3} depending upon root stock, distance from the trunk and soil depth (Castle 1980). However, in our study, the intensity of feeder roots was observed very low, which may be due to spring sampling as the root growth in citrus is periodic and maximum root growth takes place in summer months. Seasonal differences in the root density had been earlier reported by (Singh *et al*, 2012 in guava and Agnihotri *et al.*, 2009 in litchi).

Feeder root distribution at different depths x radial distances

The interaction between depth and radial distance on FRDWD was also found significant (Table-2) The maximum FRDWD was observed at 0-75 cm radial distance x 0-15 cm depth in rough lemon and cleoptera and reduced significantly at 0-75 cm radial distance x 15-30 cm depth, whereas, in troyer citrange, the maximum FRDWD was noticed at 0-75 cm radial distance x 15-30 cm depth which was at par with 0-75 cm redial distance x 0-15 cm depth zone. In troyer citrange, a substantial amount of feeder roots were found at lower depths closed to tree trunk. However, in cleoptera and rough lemon few roots grow away from tree trunk at deeper horizon also. Kurien *et al* (1991) reported that most roots actively (75-80%) was confined within a radius of 80 cm x 24 cm depth in acid lime on karna khatta. Rough lemon and cleoptera has large roots system and rough lemon bears extensive lateral and vertical development (Dalal and Thakur, 2011 and Singh *et al*, 2008) in sweet oranges.

Conclusion

The overall maximum feeder root dry weight density (FRDWD) and proportion was recorded in cleoptera followed by rough lemon and troyer citrange rootstocks. About 70% of the feeder roots were concentrated in the upper layer (0-30cm) depth i.e. intensive vertical development. In troyer citrange the feeder roots were confined closer to the tree trunk i.e. intensive lateral development. Cleoptera contained 60% feeder roots up to 150cm radial distance i.e. extensive lateral development. Whereas, rough lemon contained only 50% feeder roots up to 150cm radial distance i.e. very extensive lateral development. However, rough lemon has substantial amount of feeder roots at sub-surface soil layer i.e. 15-30cm depth away from tree trunk as compared to cleoptera and troyer. Therefore, irrigation depth, fertilizer placement and density planting should be root stock specific in citrus.

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