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Identification of feeder root zones for optimal nutrient and water uptake in subtropical fruit crops

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Abstract

The experiment was conducted to pinpoints the location-specific root system in two depths from soil surface and five horizontal distances from the tree trunk. The horizontal distance was marked in H1 (0-30 cm), H2 (31-60 cm), H3 (61-90 cm), H4 (91-120 cm) and H5 (121-150 cm), at two depths, D1 (0-30 cm) and D2 (31-60 cm). The soil of 30 cubic cm was removed with the help of a sharp spade and sieved with large mesh size to extract fine roots. The soil was soaked in water and sieved and roots were studied.The maximum root number in guava (*Psidium guajava* L.) and aonla (*Emblica officinals* L.) were recorded at 31-60 cm horizontal distance (HD) and 31-60 cm soil depth from soil surface, while in jamun it was maximum at 31-60 HD and 0-30 cm depth of from main trunk. Total root biomass represented the rooting density per unit area, maximum root mass (38.2 ± 5.74 g) in guava was recorded in 0-30 cm deep from soil surface and horizontal distance. Jamun and aonla under HDP system had maximum root biomass 31-60 cm deep from SS and 0-30 cm horizontal distance (HD) from tree trunk. The roots in length in all crops were maximum at 0-30 horizontal distance and soil depth except guava where maximum root length was noted at 31-60 cm soil depth. Guava, aonla, bael (*Aegle marmelos* L.) and jamun (*Syzigium cuminii* L.) planted under high-density planting system have maximum root number which absorb water and nutrient and supporting their trees at 0-60 cm horizontal distance and depth of 0-60 cm.Fresh root mass recorded at 31-60 cm horizontal distance from the tree trunk up to 60 cm deep from soil surface.

Key words: Aeration, Organic carbon, Root number, High density planting, Root biomass

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The roots in the soil provides anchorage, storehouse of food reserve, absorb and transport essential elements and bio-molecule to aerial parts of the trees for the vital functions, soil management factors such as tilling, mulching, water management, nutrient application, weeding etc. affect aeration, soil texture, water and nutrient availability, soil organic carbon content and root distribution pattern. Bael (*Aegle marmelos*), aonla (*Emblica officinale*), jamun (*Syzigium cuminii*) and guava (*Psidium guajava*) fruit crops are grown in wide range of soil and climatic conditions with degraded and marginal land without assured irrigation. However, for good quality fruits and high yield some crucial irrigation is required, though mostly farmers apply water through flood irrigation. A global report suggests that, 70% planet fresh water is used by farmers and 95% farmers used flood irrigation due to most energy efficient techniques. Flooding entire fields are not economical as water availability are depleting very fast. Further farmers do not have technical know-how about where and how much to apply water; hence flooding to entire field resulting wastage of water of 60-70 %. Srivastava *et al.*(2024) studied root distribution pattern, growth and yield of guava planted at 3 m × 3 m spacing on raised bed. Tree roots play physiological and biological functions have been discussed in grape. The roots lie vertically and horizontally in soil, they can penetrate up-to 600 cm in soil horizon in grape. Srivastava *et al.* (2024) reported that soil condition influence the root growth and total biomass of the fruit plants. Different fruits crops in same condition of soil profile may have different behavior (Southey and Archer, 1988; Williams and Smith, 1991) noted the tree genetic factor may affect root density, therefore genetically different fruit trees may have different root distribution pattern. The distribution of roots is the complex function decided by various factors, viz. species, variety, tree age, soil texture, cultural practices (Singh and Mishra, 2000). Root distribution study is location-specific owing to soil pedology and edaphic factor of location while root density is genetically controlled. Therefore, an experiment was conducted to identify feeder root zones in subtropical fruit crops.

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MATERIALS AND METHODS

The experiment was conducted at ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, representing subtropical climate located at 26° 51' 0.0000" N and 80° 56' 59.9892"E withannual rainfall of 750-800 mm. The soil is coarse, sandy loam, clay contentof 1.6-3.1% and pH ranging 7 to7.5. The trees during 2021and 2022 were>20 years old planted at 5 m× 5 m. The rooting pattern was studied in two depths from soil surface and five horizontal distances from tree trunk. The entire tree basin was divided in different blocks as per horizontal distance from trunk and depth wise with the help of measuring scale (Figs 1 and 2) and root excavation was carried out during spring season. The horizontal distance was marked in H_1 (0-30 cm), H_2 (31-60 cm), H_3 (61-90 cm),

H_4 (91-120 cm), H_5 (121-150 cm) with two depths, D1 (0-30 cm) and D2 (31-60 cm) from soil surface. Soil of 30 cubic cm was removed with the help of a sharp spade or shovel collected in plastic try, weed roots removed and was sieved with large mesh size after that again filled the soil in bucket and filled with water to extract fine roots too.

The soil strained 2-3 times till all the roots were collected from. Total roots from each block were counted carefully and expressed in number. Total root collected from each block which ranged from 0.2 cm thick to more than 1.5 cm thick was weighted with digital weighing balance and expressed in gram. The root length was measured using digital vernier caliper and screw gauge (model Yuzuki). The root thickness was recorded with digital vernier caliper or digital screw gauge. Two factorial randomized complete block design was employed to analyze the data. The data was analyzed using Rprogramming. Tukey's Honest Significant Difference (HSD) test was performed as a post hoc test to assess the significance of differences between pairs of group means.

RESULTS AND DISCUSSION

In guava, highest number of roots was observed at a horizontal distance of 31–60 cm from the trunk and at a vertical depth of 31–60 cm (54.2±9.3)(Fig. 1). However, this was not significantly different from the number of roots found at a horizontal distance of 0–30 cm and a depth of 31–60 cm (44.2±7.93). A total of 27 roots were found at a horizontal distance of 31–60 cm and a depth of 0–30 cm. The analysis clearly showed that the highest root density occurs at a depth of 0–30 cm. In aonla, root number per 30 cm of soil volume varied, with maximum root counts of 31.2±2.87 at a 30–60 cm horizontal distance and 0–30 cm depth, and 30.8±2.06 at a 0–30 cm horizontal distance and 31–60 cm depth (Fig 2). Minimum root numbers (2.5 ± 1.73, 3.0 ± 0.81 and 4.5 ± 1.29) noted in 121-150 cm horizontal distance, 31-60 and 0-30 cm deep respectively, root numbers were moderately recorded at 61-90 horizontal distance, 0-30 cm deep, 31-60 cm horizontal distance up to0-30 cm soil depth and 0-30 cm horizontal distance and 0-30 deep in aonla.

Maximum roots (56 ± 4.55) were recorded at 0-30 horizontal distance, 31-60 cm deep, while as moderate root number40.2 ± 4.11, 38.8 ± 7.37 at 31-60horizontal distance and 31-60 cm deep from soil surface, 31-60 cm horizontal distance and 0-30 cm deep from soil surface respectively, while minimum roots (1.75 ± 0.957, 8± 1.63) were noted in 91-120 cm horizontal distance with 0-30 cm deep from soil surface in bael. In jamun, highest root counts, 65.8 ± 7.93 and 60.5 ± 9, were observed at soil depths of 0–30 cm and 31–60 cm within the 31–60 cm and 0–30 cm horizontal distances, respectively. A moderate number of roots, 45.8 ± 4.92, was recorded at a 0–30 cm horizontal distance and 0–30 cm depth. The lowest root numbers, 4.5 ± 1.29, were noted at a 61–90 cm horizontal distance and at soil depths of both 0–30 cm and 31–60 cm.

Total root weight having fibrous type recorded in all four crops at different horizontal distance and depth. Maximum root mass (g) 38.2 ± 5.74 (g) were recorded in 0-30 cm, horizontal distance and 0-30 cm deep and moderate roots in mass recorded (17.8 ± 4.2 g) in 0-30 cm horizontal distance and 31-60 cm deep from soil surface. However, minimum roots 2.65 ± 0.507 g, 2.85 ± 0.889 g, noted in 91-120 cm horizontal distance 31-60 cm deep from soil surface and 121-150 cm horizontal distance, and 0-30 cm deep from soil surface respectively in guava (Table 1). In aonla, highest root mass (49.2 ± 5.94 g) was found at a 0–30 cm horizontal distance and 31–60 cm depth.

Moderate root mass (21.4 ± 10.5 g) appeared at 31–60 cm distance and 0–30 cm depth, while the lowest (3.52 ± 3.75 g) was at 121–150 cm distance and 31–60 cm depth (Table 1). In bael, highest root mass (58.5 ± 6.81 g) was found at 31–60 cm horizontal distance and 0–30 cm depth, with moderate roots (23.2 ± 2.5 g) at 61–90 cm distance and 31–60 cm depth. The lowest root mass (5.25 ± 2.0 g) was recorded at 61–90 cm distance and 0–30 cm depth, as well as at a 91–120 cm distance at both 0–30 cm and 31–60 cm depths (Table 1). For jamun, maximum root mass (133 ± 4.24 g, 141 ± 9.76 g) occurred at 0–30 cm distance at 0–30 cm and 31–60 cm depths, while moderate roots (73.5 ± 2.65 g, 43.5 ± 2.65 g) were at 31–60 cm distance at both depths. The minimum root mass (8.65 ± 2 g, 8.18 ± 0.98 g) was observed at a 91–150 cm distance at 31–60 cm and 0–30 cm depths (Table 1).

The data revealed that longest root (22.8 ± 7.14 cm, and 19.2 ± 1.7 cm)was noted in 0-30 cm horizontal distance from tree trunk, 0-30 cm depth of soil surface in guava,while smallest roots (10.5 ± 6.6 and 10.8 ± 8.81 cm)was recorded in 31-90 cm horizontal distance and 0-60 cm deep from soil surface (Table 2). Aonla recoded longest roots 28.2 ± 2.6 cm at 0-30 cm horizontal distance at 31-60 cm depth of soil surface and medium root length (17.8 ± 7.37 cm) recorded in 0-30 cm horizontal distance at 0-30 cm depth of soil surface. Smallest roots 8.25 ± 6.6 cm, 8.75 ± 4.19 cm were recorded in 121-150 cm horizontal distance and 0-60 cm depth from soil surface (Table 2).

Longest roots (19.21 ± 8.18 cm) noted in 0-30 cm horizontal distance at 0-30 cm depth from soil surface, smallest roots of 6.8 ± 2.56 cm, recorded in 121-150 cm horizontal distance and 31-60 cm deep in Jamun (Table 2). The average root number which comprise fibrous, thin, thick and very thick roots vary from main trunk to out wards in all crops planted under high density system.In guava,

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aonla and bael maximum average roots recorded 31 cm to 61 cm of horizontal distance from tree trunk in contrary to the jamun 0-30 cm horizontal distance exhibited maximum rootsper block. Similarly, more quantity of roots was noted in 0-60 cm of horizontal distance from tree trunk up to 0-30 cm soil depth in guava, aonla, bael and jamun under high density planting system.

These results are in agreement with (Darmwal*et. al.,*2018) in mandarin citrus during spring season. Misra and Jaiswal, (2001), reported maximum concentration of weight of fibrous nature roots in Karonda recorded at 0-20 cm deep from soil surface it decreased with increasing the soil depth.Root dry weight indicating the amount of carbon in root system which gives an initial estimate of carbon costs of producing and minatory the roots.As we move outward from main trunk of tree the dry weight of all category of roots were reduced significantly decreased, as reported by (Singh and Misra, 2000) in bael during spring season, similar findings were also reported by (Misra and Jaiswal 2001, Misra and Dabral, 2005) reported that in litchi, maximum weight of active roots were recorded at 0-30 cm deep from soil surface and root concentration drastically decreased with increasing soil depth, in 31-60 cm depth from soil surface.

Similar observations were recorded by (Rathore *et.al.,*2013) that root density was found maximum at nearest radial distance from tree trunk in aonla. Nagrojah, (1987) also reported root concentration in 40-60cm depth and decreased after wards. Root length influenced the nutrient and water uptake in the plant system rather than root mass (Gardener 1964, Nye and Tinker 1969). The root length densities of most crops decreased with the depth and horizontal distance from tree. The branching model of root is the indicator of different root functions (Van Noordwijk and Willigen, 1991). Length of longest root roughly explains the exploration of the soil zones. Proximal root diameter and total root length of all root link depend upon root branching pattern (Van Noordwijk*et al.,*1991).

Majority of roots at deeper layers of soil surface in Aonla and Jamun under HDP system indicated that the trees having ability to extracts water from lower horizons. Importance of deeper tree roots was described by (Stone and Kalisz, 1991) and (Akinnfesi *et. al.* 2004). He further stated that rooting depth of different species in plant system is crucial to determine competition for water and nutrients, however the roots are shallow in annual crops.

CONCLUSION

It is concluded that maximum roots in guava and aonla were recorded at 31-60 cm horizontal distance and 31-60 cm depth from soil surface, while in jamun roots were maximum at 31-60 HD and 0-30 cm depth from soil surface from main trunk.Jamun and aonla planted under high-density planting system having maximum root biomass 31-60 cm deep from SS and 0-30 cm horizontal distance(HD) from tree trunk, while in bael and guava maximum roots biomass were observed at 0-30 cm deep from soil surface and 0-30 cm HD from tree trunk except in bael where more root mass were noted 31-60 cm HD.

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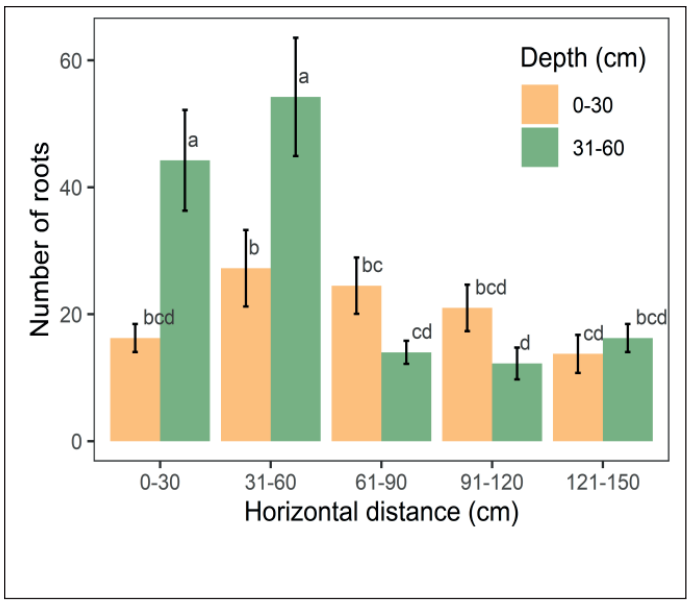


Fig. 1: Effect of horizontal distance and depth on number of roots in guava

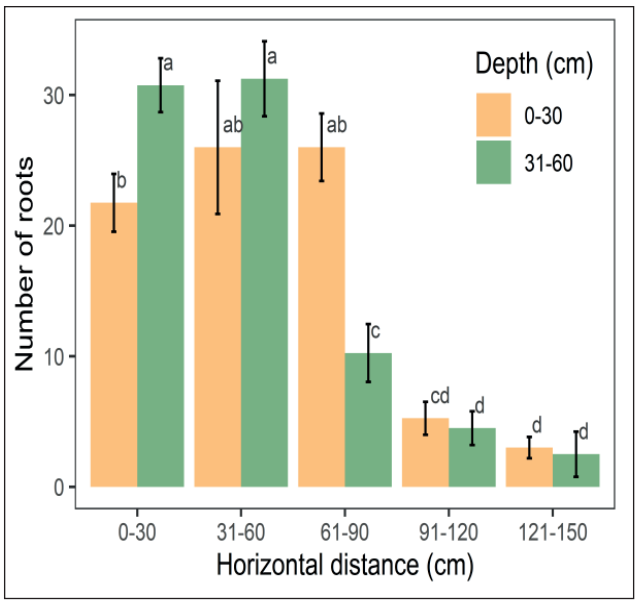


Fig. 2: Effect of horizontal distance and depth on number of roots in aonla

Table 1: Effect of horizontal distance (HD) and depth on root weight (g)

Horizontal distance (cm)	Depth (cm)	Guava	Aonla	Bael	Jamun
0-30	0-30	38.2±5.74a	10.8±6.34bcd	13.5±2.51b	133±4.24a
0-30	31-60	17.8±4.27b	49.2±5.94a	11.7±5.39b	141±9.76a
31-60	0-30	12±3.16bc	7.24±1.9cd	58.5±6.81a	73.5±2.65b
31-60	31-60	7.75±2.22cd	21.4±10.5b	23.2±2.5b	43.5±2.65c
61-90	0-30	8.75±2.06cd	18.2±10.3bc	5.25±2.06b	21.7±4.98d
61-90	31-60	6.48±2.07cd	11.4±11.4bcd	22.1±24.7b	12±2.16de
91-120	0-30	9.6±4.24cd	12.2±10.4bcd	9.07±1.35b	33.8±4.2c
91-120	31-60	2.65±0.507d	8.5±2.38bcd	7.71±1.25b	8.65±2.06e
121-150	0-30	2.85±0.889d	7.75±4.27cd	17.4±1.7b	8.18±0.984e
121-150	31-60	5.82±2.79cd	3.52±3.75d	15.2±2.88b	7.62±1.11e

Table 2: Effect of horizontal distance (HD) and depth on root length

Horizontal distance (cm)	Depth (cm)	Guava	Aonla	Bael	Jamun
0-30	0-30	19.2±1.71a	17.8±7.37a	13±7.83a	19.2±2.06a
0-30	31-60	22.8±7.14a	11±7.16a	11±6.83a	16±1.83a
31-60	0-30	11.5±6.56a	11.8±7.59a	11±8.04a	14±8.21a
31-60	31-60	10.5±6.61a	11.2±7.14a	13±9.59a	11±6.58a
61-90	0-30	10.8±8.81a	13.1±8.57a	9.5±5a	13±5.72a
61-90	31-60	15.5±5.2a	10±7.53a	9.5±5.51a	15.2±13.3a
91-120	0-30	13±5.16a	28.2±28.6a	14.5±8.19a	8.75±1.26a
91-120	31-60	13.5±2.38a	9.25±5.44a	7±3.92a	11.8±4.79a
121-150	0-30	17.8±3.3a	8.25±6.6a	9.75±6.95a	10.2±4.11a
121-150	31-60	12.8±3.3a	8.75±4.19a	11.5±6.45a	6.75±1.71a

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