



Studies on Root Architecture in Elephant Foot Yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson)

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Abstract

Experiments were conducted at ICAR-CTCRI during 2016 and 2017 to study the rooting pattern of elephant foot yam, variety Gajendra under drip irrigation and rainfed conditions, by growing the crop in semi permanent cement tanks and periodical uprooting. The root system, emerging from the newly developing corms, was shallow growing to a maximum depth of 30-40 cm, but spread horizontally upto 1.2 m. The pattern of rooting was more or less similar during both the seasons. Number of roots, length and root biomass increased gradually from sprouting, and reached maximum at full canopy development stage or 3 MAP. These parameters declined with corm bulking and reached minimum at crop senescence. Both number of roots, root dry matter and depth of rooting were less under limited soil moisture. However, rainfed crop retained more number of lengthy roots, and biomass towards later stages than irrigated crop.

Key words: Elephant foot yam, root architecture, root dry matter, root length

Introduction

Root architecture plays an important role in plant development and good root architecture improves the capacity to absorb water and nutrients and provides higher tolerance to abiotic and biotic stress factors (Fita et al., 2006). The plant root system takes up water and dissolved nutrients from the soil; therefore the size and extent of the root system are important for plant development, yield, and survival under adverse conditions. Plants which have more root-soil interfaces are likely to be more efficient in capturing soil resources. Drought, which is a major constraint to the growth of many crops including root and tuber crops can be overcome to a greater extent by evolving varieties with good root establishment. Measurements of root system parameters are tedious and time-consuming (Tracy et al. 2011, Silberbush 2013, Khan et al., 2016). Therefore, most studies examine only a small part of the total plant material and comprehensive studies await improved methods for phenotyping.

Root and tuber crops are physiologically and botanically a diverse group of plants with a common underground storage organ for carbohydrates. Although cereals dominate human food systems, the storage organs produced belowground by root and tuber crops are the second most important source of carbohydrates worldwide (Villordon et al., 2014) and the most important food source in Africa (Sanginga, 2015). Tuber crops are generally propagated from vegetative materials, not seeds. Cassava and sweet potato are grown from stem cuttings, potato and yams from tubers, and taro from suckers, corms or cormels. In all cases, the root system comprises adventitious roots derived from non-root tissue (Steffens and Rasmussen, 2016).

Elephant foot yam (*Amorphophallus paeoniifolius*) is one of the tropical tuber crops which is cultivated mostly in Asian and South east Asian countries as a vegetable crop. The crop is propagated vegetatively by means of tubers which are called corms. Either full corms or cut pieces of corms can be used for planting. Knowledge concerning

the rooting habits of this crop is important to understand how it acquires water and nutrients including the total quantification of root mass and spatial distribution in soil. Mostly elephant foot yam is intercropped with other crops such as coconut, banana, maize, pulses and vegetables, in tropical regions information on the spatial distribution of the root system is especially crucial to understand the underground interaction and is helpful to establish a suitable intercropping system. In the present study, preliminary attempts were made to study the root development of the crop once the corms are planted in soil until the time of harvest, which takes almost 8-10 months.

Materials and Methods

Experiments were conducted at ICAR-CTCRI during 2016 and 2017 to study the rooting pattern of elephant foot yam, variety Gajendra under drip irrigation and rainfed conditions. Semi permanent cement tanks of 2m x 2m x 0.6 m were constructed with hollow bricks and filled with soil. The textural analysis of filled soil was carried out and the physical and chemical properties of the soil are presented in Table 1. The crop was planted in March during both the seasons. The crop received a total effective rainfall of 771 mm during the first season and 683 mm during the second season.

Out of the 18 tanks in the structure, 9 were given with drip irrigation and the rest 9 were left as rainfed. Full corms of one kg were treated with cowdung slurry and planted at the centre of each tank. Drip irrigation was

given whenever there was no rain compensating for 100% of evaporation loss. Once the corms started sprouting, observations on roots were recorded at different stages as follows:

A stage: Sprouting of corms

B stage: Shoot elongation

C stage: Leaf emergence

D stage: Canopy opening

E stage: 3 months after planting

F stage : 5 months after planting

G stage: Senescence stage

Destructive sampling was done at each stage by sufficiently moistening the soil in the tank and uprooting the plants. Observations ie., number of roots, maximum root length, average root length, average root diameter, fresh weight of roots, and root dry weight were recorded. The biomass partitioning at different stages was also recorded by taking the fresh and dry weight of component parts viz., leaf, pseudostem (shoot), roots and corm. The average of the two years were taken and the trend of the values were assessed for the root architecture study.

Results and Discussion

The planted corms started sprouting within 30-40 days under irrigated conditions and 35- 50 days under rainfed conditions, by initiating the roots radiating from the central bud. As the corms sprouts, the new daughter

Table 1. Parameters of experimental soil used for the study

Soil properties	Irrigated tanks		Rainfed tanks	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Sand (%)	67.87	66.62	69.21	70.19
Silt (%)	7.21	5.19	6.12	5.92
Clay (%)	24.92	28.19	24.67	29.81
Bulk density	1.29	1.37	1.31	1.34
Particle density	2.0	2.08	2.07	2.14
Water holding capacity (%)	27.22	26.79	30.49	28.91
Porosity (%)	37.56	38.48	40.23	40.19
pH	5.02	5.06	5.05	5.03
Organic Carbon (%)	0.72	0.68	0.71	0.70
Av. N (kg ha ⁻¹)	262	254	273	252
Av. P ₂ O ₅ (kg ha ⁻¹)	56	58	55	63
Av. K ₂ O (kg ha ⁻¹)	176	170	172	169

corms also start initiating from the base region of pseudostem and roots emerge from the surface of the newly developing corms, which is the modified stem for storage. The roots are adventitious, white or off white in colour with many lateral feeding roots extending throughout its length.

Root system in elephant foot yam was found to be highly superficial, and grow to a maximum depth of 40 cm in the present study and unlike other crops, the lateral roots with plenty of root hairs help in absorption of water and nutrients, rather than anchorage. Growth of lateral roots allows greater access to soil resources than is possible by root axes alone and contribute significantly to root architecture.

Number of roots

Number of roots followed a growth curve pattern from sprouting to senescence. Number ranged from 37 to 608 at various stages of development for rainfed crop during the first season and 43 to 626 for the irrigated crop.

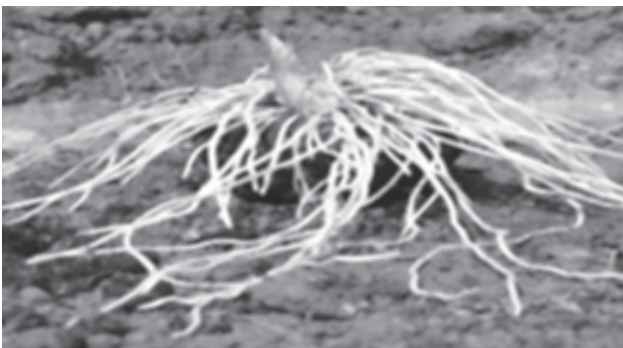


Fig. 1a. Sprouting



Fig. 1b. Elongation



Fig. 1c. leaf emergence

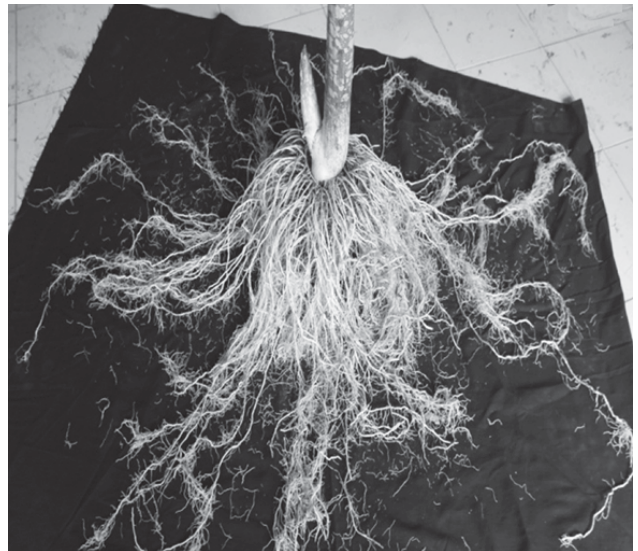


Fig. 1d. 3 MAP



Fig. 1e. Senescence

Table 2. Root distribution of elephant foot yam at various stages (mean of 2 seasons)

Stages	Lateral root spread (cm)		Depth (cm)		Root dry matter (g)	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
A	53.2	48.8	12	10	9.0	8.0
B	78.9	82.8	22	21	38.7	31.7
C	86.0	90.6	31	28	39.3	35.8
D	110.4	114.7	40	32	48.5	52.5
E	118.2	120.6	35	30	57.2	41.8
F	54.2	99.6	32	27	27.3	34.5
G	40.0	46.1	28	20	16.6	16.4

During the second season, the number ranged from 65 to 331 and 43 to 626 respectively for the rainfed and irrigated crop at different stages. Maximum number of roots was produced at E stage, i.e., 3 MAP during the first season for both the crops. However during the second season, maximum root number was seen at C stage for irrigated crop and at E stage for rainfed crop. In all the cases, the least number of roots was recorded at the senescence stage.

Length of roots

Maximum root length (135.5 cm) was achieved by the rainfed crop and irrigated crop (127.8 cm) during the first season at D stage. At sprouting stage, root length of 40.8 cm and 46.5 cm were recorded under rainfed and irrigated situations during the first season. During second season it was 56.7 cm and 59.8 cm respectively for rainfed and irrigated crop. Maximum length was attained by roots under rainfed situations (106.6 cm) and irrigated conditions (126.4 cm) at E stage, i.e., 3 MAP during second season. The root length increased gradually upto canopy emergence and more or less sustained upto 3 MAP. Then, it declined, reaching the minimum at senescence stage. The root length was more for rainfed crop especially, towards later stages of growth compared to irrigated crop.

Average length of roots ranged from 19.2 cm to 94.6 cm under rainfed situations at different stages during first season and 28.4 cm to 61.8 cm during the second season. Whereas, under irrigated conditions, the average root length was 25.5 cm to 97.3 cm and 18.6 cm to 68.7 cm for the first and second season respectively. Size of roots (diameter) increased from sprouting gradually reaching the maximum at senescence under both the moisture conditions. Root diameter ranged from 1.2 to 2.9 mm for irrigated crop and 1.2 to 2.8 mm for rainfed crop.

Elongation of roots reached a maximum at 90 DAP and root thickening occurred thereafter.

It was observed that the roots radiated horizontally from the crown of the planting sett, remaining shallow and with relatively little branching until they were near their maximum length when they branch and descend to around 30 to 40 cm depth. Roots grew more deep with irrigation than rainfed situations. Relatively few root branches and fine roots were found within the planting mound after tuberization, and roots started developing on the newly developed tubers or corms.

In the tanks with filled soil, roots could penetrate freely on all sides of the plants. During first season root growth was more or less same with adequate rains. In general, number of roots and maximum length were less during second season wherein rainfall availability was less compared to first season, especially during initial months. However, average length of roots was more under rainfed conditions, but root dry weight declined with less rains which indicates less vigour of roots. Ravi et al. (2011) also reported decrease in root length during dry seasons in elephant foot yam. Towards later stages, rainfed crop retained more number and length of roots compared to drip irrigated crop, the roots of which were confined to developing corms.

Root dry matter

Root dry matter production also followed a similar trend with root length and number of roots. For irrigated crop, it varied from 10.1 g at sprouting to 87.8 g at 3 MAP and 7.8 g at sprouting to 40.2 g at emergence during the first and second crop respectively and thereafter declined. For rainfed conditions, root dry matter ranged from 3.5 g to 75.6 g and 12.5 g to 29.5 g for first and second crop respectively. During both the years, dry

weight of roots was more or less same under rainfed and irrigated conditions at senescence stage (Table 2.).

In elephant foot yam it is reported that roots grow out from the surface of newly developing daughter corms at the base of the pseudostem through the remnants of the cataphylls concomitantly with leaf emergence. These roots extend horizontally and are densely distributed at a shallow depth of the top 15-30 cm soil depth which are cylindrical and 2 to 5 mm thick (Ravi et al., 2011).

Biomass partitioning

Biomass partitioning of plants at various stages followed a similar trend both under rainfed and irrigated conditions. Based on the mean values of two seasons, out of total dry matter, a major portion (56-57%) was roots at sprouting. Though at sprouting shoot biomass was less than 50%, the share increased rapidly with vegetative growth and occupied a major share upto canopy opening stage and started declining with corm development phase. Root biomass increased steadily upto full canopy opening stage and then started declining. At senescence, root biomass was only 1-2%. Corm development initiated as early with leaf elongation and

increased at a low pace during initial phases. A rapid increase was observed from 3 MAP, with declining root and shoot biomass and at senescence almost 95-96 % of the total biomass was contributed by corm (Fig. 2 and 3). It has been reported that in potato, the filling and formation of tubers will depend primarily on the availability of previously produced and temporarily stored assimilates in the stems and leaves, their capacity to store these sugars in their tissues, genetic aspects of the plant and environmental conditions under which they are being developed (Mora et al., 2005).

It was observed that, during the initial stages of development of the crop, the biomass is distributed mainly in leaves and stems; in the second phase, the mass flow towards new and existing leaves is reduced and the formation and filling of corms start. During the third part of the cycle, the corms are the organs with the highest filling capacity and they continue to grow until the harvest day, while the aerial part of the plant starts to decay. This occurs during the third to sixth month after planting. In potato, the maximum tuber formation and tuber bulking rate were reported from 60 to 90 days after crop sowing, during the large growth phase.

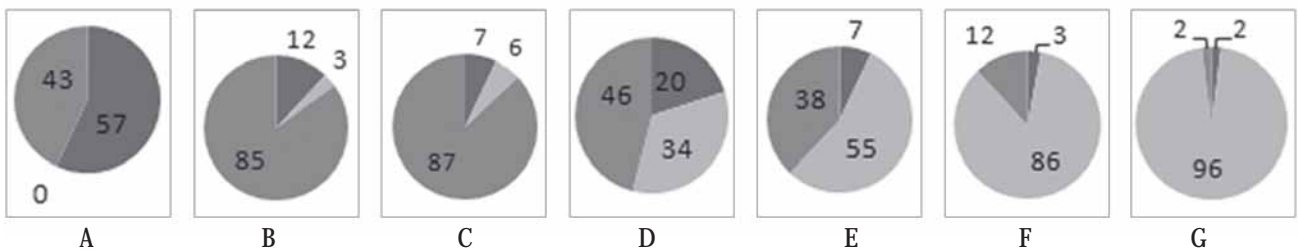


Fig. 2. Biomass partitioning at various stages of growth under irrigated conditions

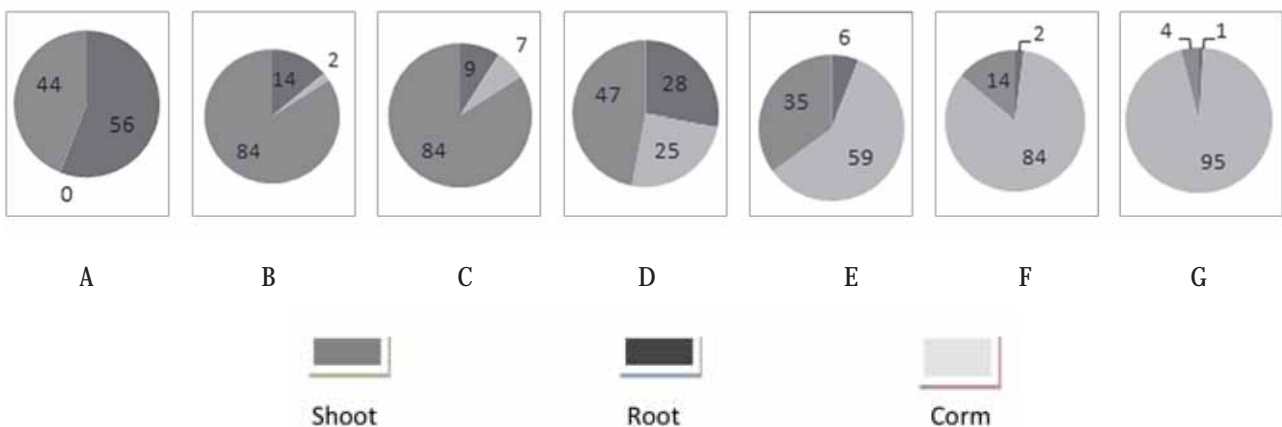


Fig. 3. Biomass partitioning at various stages of growth under rainfed conditions

This occurred because of the availability of nutrients for crop growth and development, as well as for partitioning of the dry matter production (Meena et al. (2014).

Conclusion

Elephant foot yam is grown at a spacing of 90 cm between rows and plants. The present study indicates that roots grow beyond 1.2 m laterally under adequate as well as limited soil moisture conditions. However the roots are shallow growing to a depth of 30 cm. Rooting pattern may be taken onto account while growing inter/mixed crops along with elephant foot yam.

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