CHAPTER 7
PRODUCTION AND PARTITIONING OF DRY MATTER IN THREE SWEET POTATO CULTIVARS

7.1 ABSTRACT

Growth, dry mass production and partitioning pattern of local cultivars are not known. Changes in the dry mass of tubers, stems and leaves of three sweet potato cultivars (Awasa-83, Bareda and Falaha) were studied under field conditions in Ethiopia at Awasa and Melkassa. The objective was to quantify dry mass production and partitioning during different growth stages. The experimental design was a 3 x 8 factorial experiment in a randomized complete block, replicated three times.

The quantity and pattern of dry mass produced and partitioned differed among the three cultivars. Significant differences between cultivars and sequential harvesting dates were observed for roots, stems, leaves and total dry mass at Awasa and Melkassa. There were no significant interactions between cultivars and sequential harvesting dates except for root dry mass at Awasa. At Melkassa the cultivar Bareda produced the highest root dry mass, stem dry mass, leaf dry mass and total dry mass. Cultivars Awasa-83 and Falaha did not differ significantly in root, stem, leaf and total dry mass. Falaha was the most efficient in terms of dry mass partitioning to the storage roots (73% of the biomass), followed by Bareda (67%) and Awasa-83 (59%).

At Awasa significant differences were observed in the mean root dry mass production of the three cultivars. Bareda produced the highest root dry mass. Cultivar Awasa-83 produced

significantly higher stem, leaf and total dry mass than Bareda and Falaha. The highest stem dry mass, leaf dry mass and total dry mass was produced by Awasa-83. At Awasa, Bareda was the most efficient in terms of dry matter partitioning to the storage roots (60%), followed by Falaha (52%) and Awasa-83 (48%). The relatively poor growth and yield recorded at Awasa was mainly attributed to low rainfall during the growing season of 2001.

The total dry matter produced per sampling time and the dry matter partitioned to the roots, stems and leaves at different sampling times are presented. The variability among cultivars in dry matter partitioning suggests that the development of cultivars with higher dry matter partitioning to the storage roots is possible. The early maturing cultivar Falaha partitioned a larger portion of assimilates to the storage roots earlier in the growth period, when the intermediate and the late maturing cultivars still partitioned most of the dry matter to the leaves and the stems.

7.2 INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is an important food crop grown throughout the tropics. Low sugar types generally predominate. High starch content is a desired attribute of this staple food (Mok *et al.,* 1997). The succulent, starchy storage roots of sweet potato serve as a staple food, as animal feed (Ruyiz *et al.*, 1980; Lu *et al*., 1989; Posas, 1989; Woolfe, 1992), and to a limited extent as a raw material for industrial purposes such as a source of starch and for alcohol production (Winarno, 1982; Yen, 1982; Collins, 1984).

In the United States sweet potato is grown as a table vegetable (Bonte & Picha 2000). The North American market prefers the high sugar, orange-fleshed dessert type. Sweet potato has been identified as a potentially important crop for Controlled Environmental Life Support Systems (CELSS) for manned space missions (Mason & Carden, 1982; Hill *et al*, 1984).

Staple sweet potato types typically have a white to cream flesh with a dry matter content ranging from 25% to 35%. The dry mass in sweet potato is directly correlated with starch content (Li & Liao, 1983). Dry matter content in excess of 35.0% is desired as a raw material in the starch processing industry (Mok *et al.*, 1997). However, as dry matter content increases, there is a corresponding decrease in acceptability as a table food (Lin *et al.*, 1995).

Dessert sweet potato types generally have cream to orange flesh and dry matter contents ranging from 18% to 26%, with starch contents ranging from about 13% to 22% (Picha, 1987). Cultivars showed quantitative differences in dry matter content based on harvest dates (Bonte & Picha, 2000). Little information is available on the dry matter partitioning between roots, leaves and stems, during growth and development. The crop growth period normally varies between 12 and 35 weeks (Chen & Xu, 1982; Hahn & Hozyo, 1984), but as long a duration as 25 to 50 weeks has been reported for some cultivars (Huett, 1976; Huett & O'Neill, 1976). However, most of the cultivars attain their maximum storage root yield within 12 to 22 weeks after planting (Steinbauer & Kushman, 1971; Huett, 1976; Gupta & Ray, 1979; Indira & Lakshmi, 1984; Nair & Nair, 1985; Nair *et al*., 1986; Sen *et al.*, 1990). Storage roots contain 50% to 79% starch and 4% to 5% sugar on a dry mass basis (Liu *et al.*, 1985; Lila & Bala, 1987; Lila *et al.*, 1990; Goswami 1991; Li *et al.*, 1994) or 7 to 28% starch on a fresh weight basis (Huang, 1982; Indira & Lakshmi, 1984).

Leaf area index (LAI) is the ratio of the leaf area to land area and varies widely among sweet potato cultivars and at different growth periods, depending on the number of leaves retained and their size. Changes in the leaf area index during growth occur in three phases: it steadily increases from the second week after planting in the first phase, reaching a plateau between the 8th and 16th week after planting, and declines during the third phase due to leaf senescence. The maximum LAI during the second phase varied between 2 and 11 (Yu, 1981; Agata, 1982; Bourke, 1985; Mukhopadhyay *et al.*, 1992; Bhagsari & Ashley, 1990). LAI increases with increase in temperature (Agata, 1982; Mukhopadhyay *et al*., 1992), photoperiod (Mukhopadhyay *et al*., 1992), N application (Bourke, 1985), soil moisture (Enyi, 1977; Indira & Ramanujiam, 1985; Chowdhury & Ravi, 1990), and due to staking (Bhagsari, 1990). A higher rate of K fertilization had no effect on the LAI (Bourke, 1985).

Brown (1992) estimated that a LAI of 3 to 4 is required to intercept 95% of photosynthetic active radiation (PAR) in sweet potato. Most of the cultivars maintain LAI values of 3 to 4 between 8 and 16 weeks after planting. At this LAI the maximum weekly crop growth rate (CGR) varies between 106 and 133 g/m^{-2} (Enyi, 1977; Agata, 1982; Tiwari *et al*., 1985).

According to Bonte & Picha (2000) cultivars showed significant quantitative differences in dry matter content based on harvest dates. Total dry matter production and efficiency of dry matter allocation to storage roots determine the storage root yield. The increase in total dry mass as well as storage root dry mass follow a sigmoid pattern in sweet potato (Huett & O'Neill, 1976; Enyi, 1977; Bourke, 1985; Oswald *et al.*, 1994). A few reports indicate a linear increase in total dry mass (Li & Yen, 1988; Nair & Nair, 1995) and storage root dry mass (Nair & Nair, 1995). Based on dry matter partitioning, sweet potato generally exhibits three growth phases. In the initial phase, shoot growth dominates, with a large proportion of dry matter diverted to shoot growth. This is followed by a second phase of constant partitioning of dry matter between shoot and storage root growth. During the final phase, a major portion of dry matter is partitioned to the storage roots.

Availability of adequate soil moisture prolonged total dry matter production but reduced the proportion of dry matter allocated to storage roots (Enyi, 1977). An increase in N and K fertilizers considerably increased total dry mass and storage root dry mass (Bourke, 1985; Li & Yen, 1988). An increase in plant population decreased storage root dry matter and shoot dry matter per plant but significantly increased yield per hectare (Li & Yen, 1988).

Cultivars differ in total dry mass production. Sweet potato cultivars with a high total dry mass diverted more dry matter to storage roots compared to those with a lower total dry mass (Huett & O'Neill, 1976; Li & Yen, 1988). Enyi (1977) also reported that high yielding cultivars divert more dry matter to storage roots than low yielding ones.

No published information exists on the growth and development of sweet potato under field conditions in Ethiopia. The cultivars Awasa-83, Bareda and Falaha are nationally released cultivars. Dry matter production and partitioning of these and other released cultivars are not known. Therefore the main objectives of the field trials on the production and partitioning of dry matter were to characterize the growth and development of three cultivars at two experimental sites, Melkassa and Awasa by:

- determining the change in dry mass of the leaves, stems and storage roots during growth and development (partitioning of assimilates);
- comparing the efficiency of the dry matter partitioning to the storage roots of the three cultivars;

- characterizing the canopies in terms of the leaf area index and leaf area duration;
- attempting to explain differences in growth and yield by means of growth analysis, specifically of the crop growth rate, tuber growth rate and net assimilation rate; and
- determining the optimum time of harvesting for optimum dry matter content.

7.3 MATERIALS AND METHODS

The experiments reported in Chapter 7 were conducted on the same field and under the same climatic conditions as those in Chapter 6. The chemical and physical soil properties, weather data, and cultural practices are presented in Chapter 6.

Experimental design and treatments

At both Melkassa and Awasa, a 3 x 8 factorial experiment involving three cultivars (Awasa-83, Bareda and Falaha) and eight harvesting dates in a randomized complete block design with three replications was used. These cultivars are of different maturity groups. Falaha is an early maturing cream-fleshed cultivar, which requires 90 to 105 days to mature. Bareda is an intermediate maturing cream-fleshed cultivar, which requires 120 to 135 days. Awasa-83 is a late maturing white-fleshed cultivar, which requires more than 150 days.

The growth and development of different plant components were evaluated over eight harvest dates during tuber bulking. Sampling was started 45 days after planting and continued every two weeks until 150 days after planting. There were 72 plots, each plot consisting of five rows, 3 m long with 0.6 m between rows. Each row contained 10 plants, spaced 0.3 m apart. Two border rows were disregarded and the three central rows were used for the sequential harvesting every fortnight.

At both Awasa and Melkassa Agricultural Research Centres the recommended sweet potato cultural practices were followed. Land was plowed deeply, harrowed and disced. Ridges were made using a ridger-mounted tractor. Thirty to forty centimeters long vine cuttings were prepared from the terminal and the middle portions of the vine. They were planted on 31 March 2001 at Melkassa and 6 June 2001 at Awasa. At Awasa the field experiment was conducted under rain-fed conditions. At Melkassa the rain was supplemented by furrow irrigation. No fertilizer was applied. Weeds were effectively controlled manually. No pest or disease of any consequence occurred during the growing season.

Data recorded

Serial harvesting commenced 45 days after planting. Five representative plants of each cultivar were randomly sampled from each replication. Harvesting was done in the morning (8 to 10 am). Each plot was sampled only once. Sampling continued at two-week intervals. At the final harvest, 150 days after planting, all three cultivars were still growing actively. The final harvest was dictated by tuber quality. Plants were cut at the ground level, and separated into leaf blades and vines. Fresh weights were obtained immediately after cutting. The fibrous and tuberous roots were then harvested, cleaned and weighed. Sub samples of the fresh tubers and stems were dried in an air-forced oven at a temperature of 105 °C for 48 hours and the dry mass was determined. The dry mass of the stem includes the dry mass of both the vine and leaf petioles. The dry mass of the roots includes the dry mass of the fibrous, pencil, and tuberous roots. At every sampling at

Melkassa, leaf area was measured with a LI-3100 leaf area meter (LI-inc. Lincoln, Nebraska, USA) and the specific leaf area was determined. In order to minimize variations in leaf area measurements, the leaf area index was calculated from the dry mass of the leaves and the mean specific leaf area (52 g m^{-1}).

Statistical analysis

The experimental data were subjected to standard analyses of variance using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1989) to determine the effect of main effects and the interaction between them. Differences at $P \leq 0.05$ level were used as a test of significance and means were separated using Tukey's t-test. The trials at the two sites were analyzed separately (Appendix, Tables A7.3, A7.4, A7.5, A7.7, A7.8 and A7.9).

7.4 RESULTS AND DISCUSSION

Melkassa experiment

Root dry mass

The root dry mass of the three cultivars at Melkassa is presented in Figure 7.1 and in the Appendix Table A7.1. The short season cultivar, Falaha, formed storage roots 45 days after planting, while in the case of cultivars Awasa-83 and Bareda, the first signs of tuber formation were observed 60 days after planting (Appendix, Table A7.1). At 90 days all three cultivars showed similar tuber growth (43.9 to 64.6 g dry mass per plant). From 90 days after planting clear differences in bulking rate were observed. Bareda had the highest tuber-bulking rate (13.3 g dry mass per plant per day), resulting in a final yield of 849.9 g at final harvest (150 days after planting). Falaha had an average bulking rate of 5.9 g per plant per day, resulting in a final yield of 418.9g. The long season cultivar, Awasa-83, had a bulking rate of 3.8g per plant per day, and a final root yield of 274.3g. All three cultivars were still growing actively 150 days after planting and considerable tuber bulking would have occurred if a longer growing period had been allowed. The late cultivar Awasa-83 may have been affected more than the other cultivars by terminating growth at 150 days.

Stem dry mass

The stem dry mass production of the three cultivars at Melkassa is presented in Figure 7.1. At 75 days after planting, all three cultivars showed similar stem growth (11.2 to 18.5 g dry mass per plant). From 75 days after planting clear differences in stem growth occurred. Bareda produced the highest stem dry mass of 276.5 g/plant at 150 days after planting, when it was still growing actively. Cultivars Awasa-83 and Falaha produced their highest stem dry mass of 225.4 and 110g/plant respectively at 135 days after planting, and declined thereafter. There was a significant difference in stem dry mass production of the three sweet potato cultivars during the different sampling dates at Melkassa (Appendix, Table A7.2). The observed pattern of stem growth does not reflect the accepted maturity groups. For both the early maturing Falaha and the late maturing Awasa-83 stem growth declined after 135 days, while the intermediate cultivar Bareda still exhibited active stem growth at 150 days after planting.

Leaf dry mass

The leaf dry mass production is presented in Figure 7.1. At 45 days after planting, all three cultivars showed similar leaf growth (7.8 to 11.7 g dry mass per plant) (Appendix, Table A7.3). From 75 days after planting, clear differences in leaf growth were observed. Bareda produced the highest leaf dry mass of 142.8 g/plant at 120 days after planting, but production declined thereafter. Cultivars Awasa-83 and Falaha produced the highest leaf dry mass of 166 and 90.6g/plant 135 days after planting and production for both of them declined thereafter.

Partitioning of dry matter to tubers

The partitioning of dry matter to the roots of the three cultivars is presented in Figure 7.2 and in the Appendix Table A7.4. There were differences between the cultivars in the portion of the dry matter partitioned to the roots. In the case of Falaha, a larger fraction of assimilates ranging from 29% to 73%, was diverted to the roots during the growing period. For cultivar Bareda the fraction of the dry matter allocated to the roots increased from 8 to 67% from 45 to 150 days after planting, while for cultivar Awasa-83 it increased from 4 to 53%. Although Bareda allocated less of the available assimilates to storage root growth than Falaha, a much higher final yield was produced by the cultivar Bareda. This finding differs from the results obtained by Huett & O'Neill (1976); Enyi (1977) and Li & Yen (1988), who reported that sweet potato cultivars with higher yields divert larger portions of assimilates to the storage roots.

Partitioning of dry matter to stems

The partitioning of dry matter to the stems is presented in Figure 7.2 and in the Appendix Table A7.4. The portion of the dry matter allocated to the stem during the sampling period varied among cultivars. The intermediate cultivar, Bareda, and the late maturing cultivar, Awasa-83, partitioned a larger fraction of assimilates to the stems earlier in the growth season. In the case of Bareda the stems constituted 38% of the dry mass at 45 days after planting. At 150 days after planting the stems still contained 22% of the dry mass. Cultivar Awasa-83 allotted 36% of the assimilates to stem growth at 45 days after planting. At 150 days after planting the stems still contained 29% of the dry mass. Falaha diverted the smallest proportion of assimilates to the stem growth (27% at 45 days and 15% at 150 days). A larger portion of the plant dry mass was partitioned to stems at an earlier stage of the cultivars growth. This finding is similar to the findings of Enyi (1977), who reported that shoot growth dominates during the first phase of sweet potato growth, with a large proportion of dry mass diverted to shoots.

Partitioning of dry matter to leaves

The partitioning of dry matter to the leaves of the three cultivars is presented in Figure 7.2 and in the Appendix Table A7.4. It is clear that Awasa-83 invested a larger portion of the available assimilates in leaf growth than the other two cultivars. In the case of Awasa-83 the leaves constituted 60% of the plant dry mass early in the growth season. At 150 days after planting the leaves still represented 18% of the dry mass. Falaha diverted the smallest fraction of assimilates to leaf growth (45% at 45 days and 12% at 150 days). Cultivar Bareda was intermediate in this regard with 54% of the assimilates partitioned to the leaves at 45 days. At 150 days after planting the leaves still constituted 11% of the dry mass. This study indicated that most assimilates were partitioned to the leaves at an earlier stage of growth, in agreement with the results of Enyi (1977).

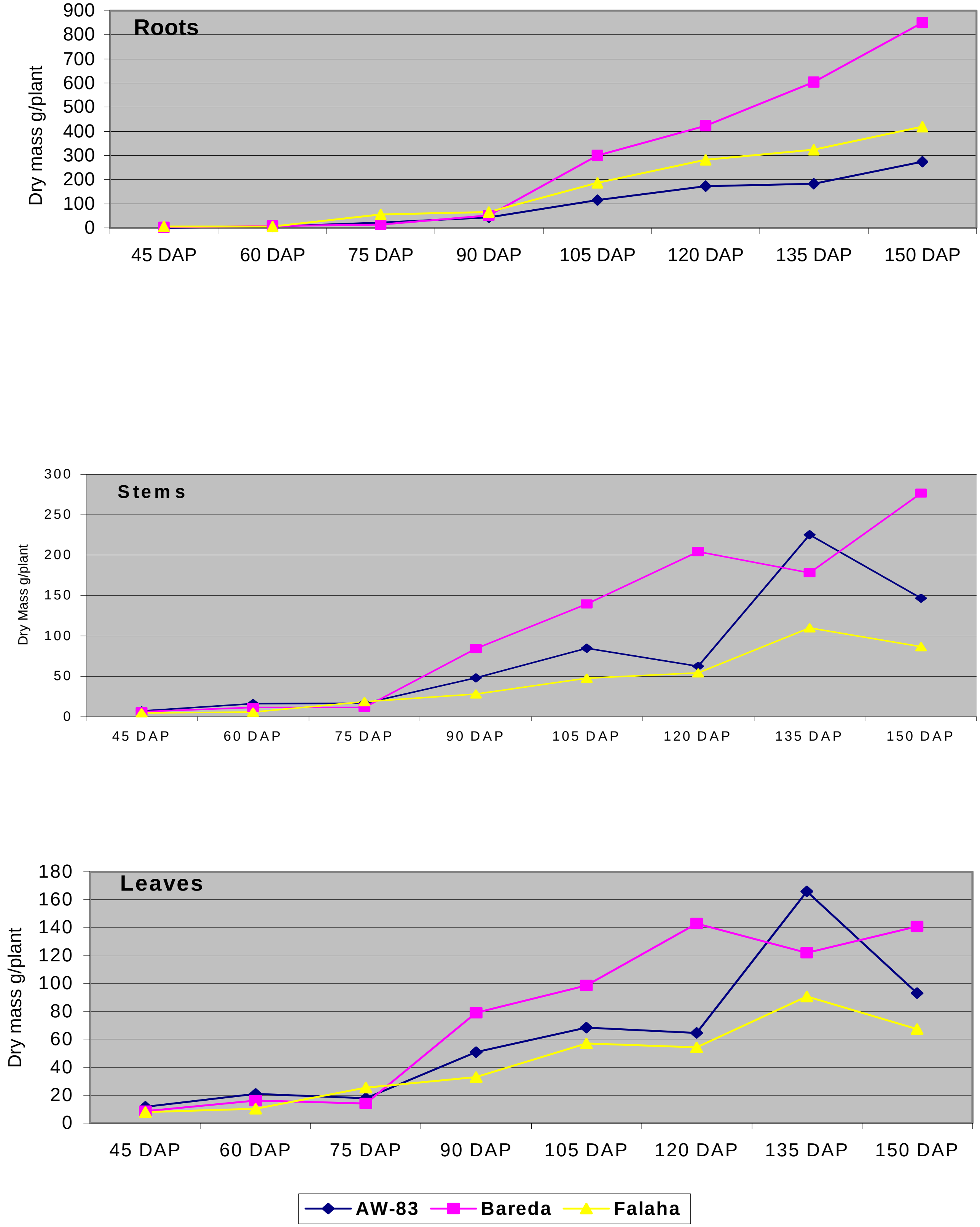

Figure 7.1 Dry mass of roots, stems and leaves of Awasa-83, Bareda and Falaha at different harvesting dates at Melkassa

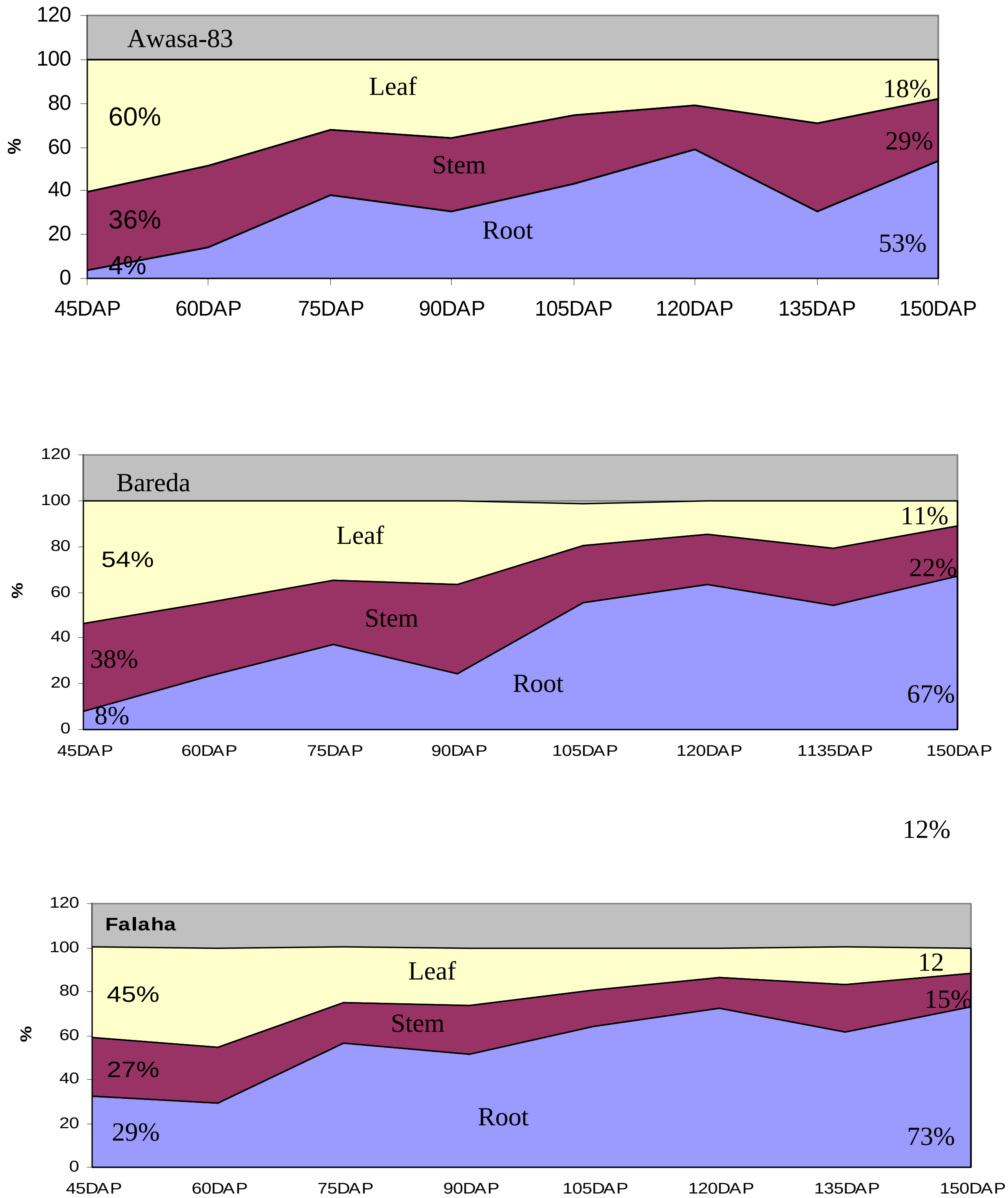

Figure 7.2 Percent dry matter partitioned to the roots, stems and leaves of the cultivars Awasa-83, Bareda and Falaha at Melkassa

Canopy development and growth rates at Melkassa

Data on the leaf area index (LAI), leaf area duration (LAD) and the net assimilation rate (NAR) are presented in Table 7.1 for the period 90 to 150 days after planting. The size (LAI), duration and efficiency (NAR) of the canopies during the period of tuber bulking should have a major influence on final yield.

The leaf area indices were relatively large, reflecting the lush canopy development at this site. Cultivar Bareda produced the largest canopy and Falaha the smallest. At the final harvest, 150 days after planting, the canopies were still active, with little or no sign of declining. The critical leaf area index (LAD_{95}) is defined as the canopy size which intercepts 95% of incoming radiation. Depending on the crop genotype, LAD_{95} values of 3 to 5 are typical for most cultivated crops. Forage crops, such as grasses, with erectophile leaf orientation may require a LAI of 8 to 10 under favorable conditions of maximum light interception (Gardner *et al*., 1994). Brown (1992) estimated that LAI of 3 to 4 is required to intercept 95% of photosyntheticaly active radiation (PAR) in sweet potato. During the tuber bulking periods Falaha and Awasa-83 produced canopies with LAI-values between 3 and 10, while Bareda had LAI-values of more than 10 for most of the tuber-bulking period. According to several authors, the LAI among sweet potato cultivars varied between 2 and 11 (Yu, 1981; Agata, 1982; Bourke, 1985; Indira & Ramanujam, 1985; Li & Kao, 1985; Tiwari *et al*., 1985; Mukhopadhyay *et al.,* 1992; Bhagsari & Ashley, 1990; Nair & Nair, 1995). Although no data to confirm the observation is available, it is suggested that all three cultivars exhibited excessive foliage development, and that cultural practices to limit foliage growth should be researched.

LAD expresses the magnitude and persistence of the leaf canopy. Leaf area duration was calculated from each sampling interval from 90 to 105 days after planting (LAD = average LAI X 15 days). The LAD during the tuber-bulking period was 751 days for Bareda with a final yield of 196t ha^{-1}. Awasa-83 produced a final yield of 56t ha^{-1} with a leaf area duration of 587 days, while with a leaf area duration of 402 days the final yield of Falaha was 95t ha^{-1}. Enyi (1977) reported that the leaf area duration of the seven cultivars he studied ranged from 240 to 616 days and there was no correlation with yield.

The NAR was calculated as the net gain of assimilates per unit leaf area per sampling cycle. Large variations in the NAR were recorded which probably reflects the inherent problem of representative sampling. However, with Bareda as the possible exception, the highest NAR values tended to occur during the 90 to 105 days interval. For the rest of the growing period, NAR showed a declining trend. The cultivar Bareda showed the highest net assimilation rate of 11.4 g m^{-2} day^{-1} between 90 and 105 days after planting, and the highest mean NAR of 7.6g m^{-2} day^{-1}. Cultivar Awasa-83 and Falaha showed mean NAR-values of 6.3 and 5.4g m^{-2} day^{-1} respectively. In this study, values of the mean NAR among cultivars varied from 37.8 to 53.2g m^{-2} $week^{-1}$, which is comparable to the highest value of the net assimilation rate 55 to 60g m^{-2} $week^{-1}$ reported by Tsuno (1971).

The crop growth rate and tuber-bulking rate were estimated from the increase in dry mass per unit of land area at each consecutive sampling period (Table 7.1). Crop growth rates include top growth and tubers and varied between 1.7 and 21.7 g m^{-2} day^{-1}. The large variation should probably be attributed to variation in the samples. Bareda exhibited the highest rate of 21.7 g

m^{-2} day^{-1}, and the highest mean crop growth rate of 16.4 g m^{-2} day^{-1} (or 115 g m^{-2} $week^{-1}$) during the tuber-bulking phase. The comparable mean crop growth rates for the other two cultivars was 6.8 g m^{-2} day^{-1} for cultivar Awasa-83 and 6.3 g m^{-2} day^{-1} for Falaha. The mean crop growth rate of 120g m^{-2} $week^{-1}$ reported by Tsuno (1971) is comparable with the mean CGR of 115g m^{-2} $week^{-1}$ for Bareda. A mean crop growth rate of 20g m^{-2} day^{-1} (200kg ha^{-1} day^{-1}) is considered acceptable for most crops, particularly C_3 types. A mean crop growth rate of 30 g m^{-2} day^{-1} (300 kg ha^{-1} day^{-1} for grain) was recorded for C_4 types such as maize (Gardner *et al.,* 1994).

Tuber growth rate varied from less than one to more than 16 g m^{-2} $day^{-1,}$ which is equal to 112g m^{-2} $week^{-1}$). During the bulking period, Bareda had a mean tuber growth rate of 11g m^{-2} day^{-1} compared to rates of less than 5 g m^{-2} day^{-1} for the other two cultivars. Enyi (1977) reported that the tuber-bulking rate of seven sweet potato cultivars ranged from 50 to 131 g per plant $week^{-1}$ which is 22 to 57 g m^{-2} day^{-1}. The mean tuber bulking rate for the three cultivars examined in this study, ranged from 24 to 77 g m^{-2} day^{-1} is slightly higher than the results of Enyi, (1977) who recorded that a bulking rate of 22 to 57 g m^{-2} day^{-1} for seven cultivars. In terms of fresh mass, a rate of 11 g m^{-2} day^{-1} is equivalent to 3.2t tubers ha^{-1} $week^{-1}$. The large range of recorded tuber bulking rates clearly emphasizes the importance of maintaining agronomic inputs to optimize yield.

Table 7.1 Leaf area index, leaf area duration, net assimilation rate, and crop and tuber growth rate at Melkassa

Time	LAI			Cumulative LAD days			NAR g m^{-2} d^{-1}			CGR g m^{-2} d^{-1}			TGR g m^{-2} d^{-1}		
	Aw-83	**Bareda**	**Falaha**	**Aw-83**	**Bareda**	**Falaha**	**Aw-83**	**Bareda**	**Falaha**	**Aw-83**	**Bareda**	**Falaha**	**Aw-83**	**Bareda**	**Falaha**
90 DAP	5.5	8.3	3.3				5.8	7.8	2.8	5.8	11.7	1.7	1.5	2.5	0.6
105 DAP	7.2	10.5	6.1	95	141	71	6.4	11.4	10.1	8.3	21.7	11.1	4.7	16.5	8.2
120 DAP	6.6	15.4	5.5	104	194	87	2.4	4.3	6.7	2.8	12.2	6.6	3.9	8.2	6.3
135 DAP	17.6	12.6	9.9	182	210	116	4.2	6.6	5.0	13.6	15.2	8.9	0.7	12.0	2.8
150 DAP	9.9	14.8	7.2	206	206	128	1.9	7.8	2.4	3.4	21.1	3.2	6.0	16.4	6.3
Total	-	-	-	587	751	402									
Mean	-	-	-				6.3	7.6	5.4	6.8	16.4	6.3	3.4	11.1	4.8

Data not statistically analyzed

Awasa experiment

Root dry mass

The root dry mass production of the three cultivars was much lower at Awasa than at Melkassa, (Figure7.3 and Appendix, Table A7.5). All the cultivars exhibited storage root formation 75 days after planting. There were differences in root dry mass production of the three cultivars from 90 days after planting (Appendix, Table A7.5). Awasa-83 had the highest tuber-bulking rate (3.1g dry mass per plant day^{-1}), resulting in a final yield of 204 g at the final harvest (150 days after planting). Falaha had an average bulking rate of 1.9g per plant day^{-1}, resulting in a final yield of 147g and Bareda had a similar bulking rate during the mean bulking period from day 90 to day 150 and a final yield of 143.9g. All three cultivars were still growing actively 150 days after planting and considerable tuber bulking would have occurred if a longer growing period had been allowed. The late cultivar, Awasa-83, may have been affected more than the other cultivars by terminating growth at 150 days.

Stem dry mass

The stem dry mass production of the three cultivars at Awasa is presented in Figure 7.3 and in the Appendix Table A7.6. Cultivar Awasa-83 produced the highest stem dry mass of 157.3g/plant at 150 days after planting, while Falaha and Bareda produced approximately 50% lower stem dry masses. During the latter part of the growing season active vegetative growth still occurred in the case of cultivar Awasa-83, resulting in an increased stem mass, while stem mass of the other two cultivars tended to stabilise after day 105.

Leaf dry mass

The leaf dry mass production of the cultivars, Awasa-83, Bareda and Falaha, is presented in Figure 7.3 and in the Appendix Table A7.7. At 45 days after planting, clear differences in leaf growth were observed. Cultivar Awasa-83 produced the highest leaf dry mass of 68g/plant at 150 days after planting. Bareda and Falaha respectively produced 45g and 65g/plant at 105 days after planting and leaf production by both of them declined thereafter.

Partitioning of dry matter to tubers

Data on the partitioning of dry matter to roots of the three cultivars is presented in Figure 7.4 and in the Appendix Table A7.8. There were differences between cultivars in the proportion of dry matter partitioned to the roots. Bareda partitioned a larger fraction of assimilates, ranging from 9 to 60% to the roots during the growing period. For Falaha the dry matter portion allocated to root growth increased from 14 to 52% from 45 to 150 days after planting, while for cultivar Awasa-83 it increased from 22 to 48 %. Although cultivar Awasa-83 partitioned less of the available assimilates to storage root growth than Bareda and Falaha, it produced a much higher final yield than Bareda and Falaha. This finding differs from the results obtained by Huett & O'Neill (1976); Enyi (1977); Li & Yen (1988) who reported that sweet potato cultivars with higher yields divert larger portions of assimilates to the storage roots. It is an important observation which deserves further attention from agronomists and plant breeders.

Partitioning of dry matter to stems

The partitioning of dry matter to the stems of the three cultivars is presented in Figure 7.4 and in the Appendix Table A7.8. The stems of cultivar Awasa-83 constituted 38% of the dry mass at 45 days after planting. At 150 days after planting, the stems still contained 36% of the total dry mass. Cultivar Falaha allocated 37% of the assimilates to stem growth at 45 days after planting. At 150 days after planting, the stems still represented 28% of the dry mass. Bareda diverted less assimilates to the stem growth (32% at 45 days and 29% at 150 days). It is clear that larger portions of the plant dry mass were partitioned to the stems during earlier stages of growth. This finding is similar to the results obtained by Enyi (1977), who reported that shoot growth dominates during the first phase of sweet potato growth, with a large proportion of dry mass diverted to shoots.

Partitioning of dry matter to leaves

The partitioning of dry matter to the leaves of the three cultivars is presented in Figure 7.4 and in the Appendix Table A7. 8. The leaves of cultivar Bareda constituted 58% of the plant dry mass early in the growth season. At 150 days after planting, the leaves represent 11% of the dry mass. Falaha diverted 49% of the total dry mass to leaf growth early in the season. At 150 days after planting the leaves constituted 20% of the dry mass. Cultivar Awasa-83 invested the smallest fraction of assimilates in the leaf growth (40% at 45 days and 16% at 150 days). This study indicated that most assimilates were partitioned to the leaves at an earlier stage of growth. This finding is in agreement with the results obtained by Enyi (1977).

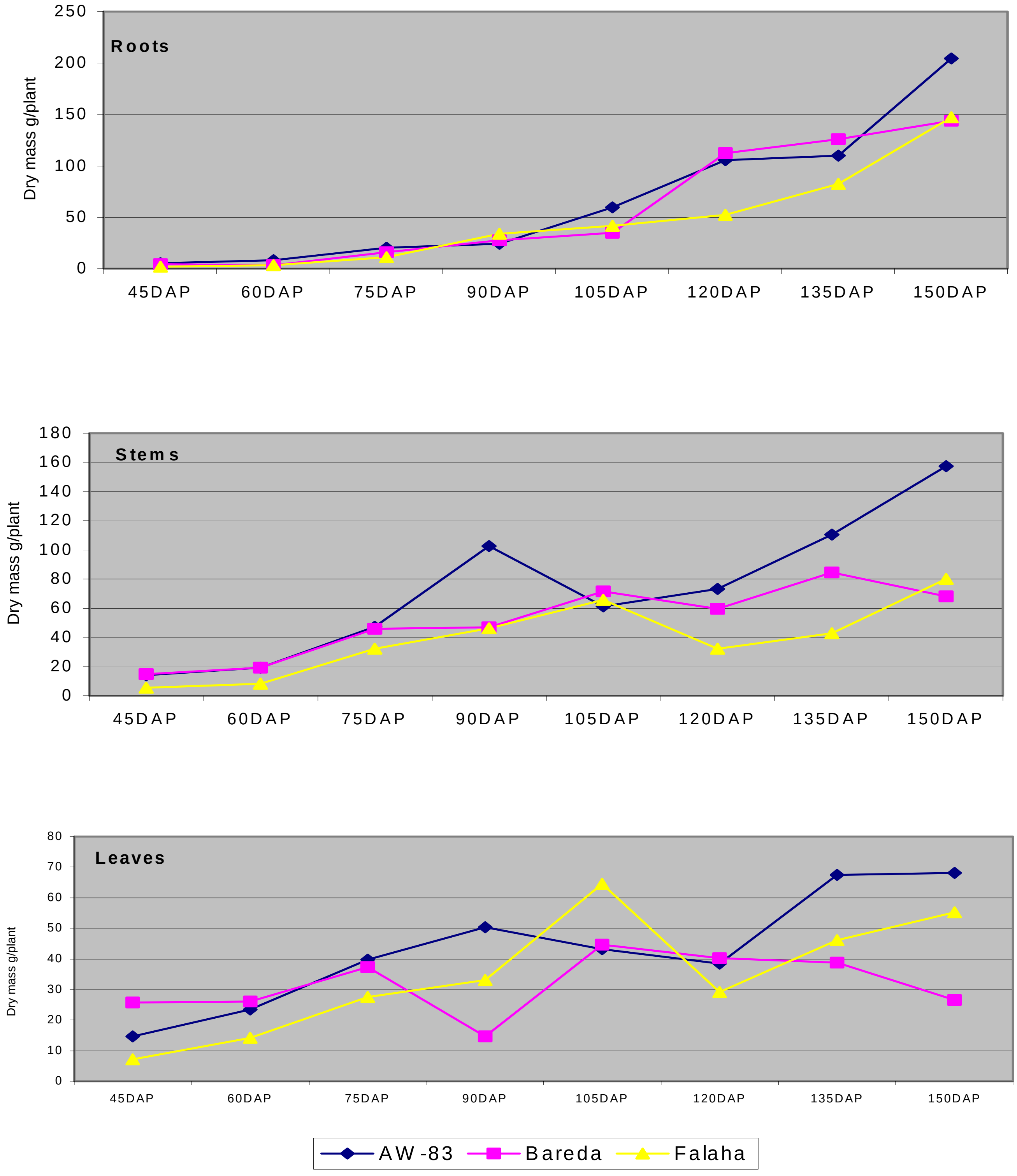

Figure 7.3 Dry mass of roots, stems and leaves of Awasa-83, Bareda and Falaha at different serial harvesting dates at Awasa

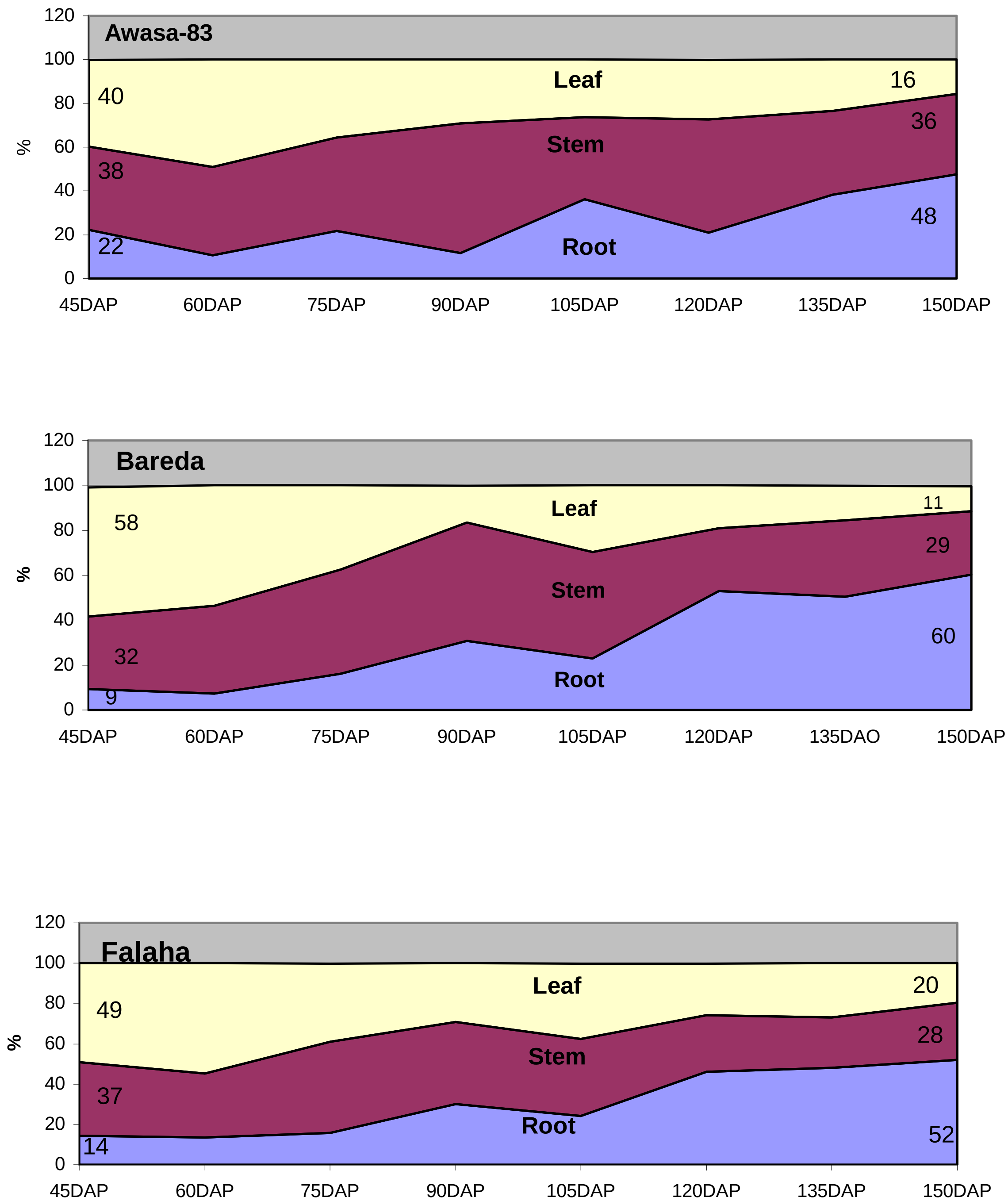

Figure 7.4 Percent dry matter partitioned to the roots, stems and leaves of the cultivars Awasa-83, Bareda and Falaha at Awasa

Canopy development and growth rates at Awasa

Although the leaf area indices obtained at Awasa for the three cultivars were higher than those reported by other authors, it was lower than at the Melkassa site. Data on the leaf area index (LAI), Leaf area duration (LAD) and the net assimilation rate (NAR) are presented in Table 7.2 for the period 90 to 150 days after planting. Bareda and Falaha maintained canopies with LAI values between 3 and 10 for most of the tuber-bulking period, while those of cultivar Awasa-83 ranged between 6 and 12. According to several authors LAI varied between 2 and 11 (Yu, 1981; Agata, 1982; Bourke, 1985; Indira & Ramanujam, 1985; Li & Kao, 1985; Tiwari *et al*., 1985; Mukhopadhyay *et al.*, 1992; Bhagsari & Ashley, 1990; Nair & Nair, 1995).

The crop growth rates and tuber bulking rates were estimated from the increase in dry mass per unit of land area at each consecutive sampling period (Table 7.2). Crop growth rates include top growth and tubers and varied between 2.4 and 9.8g m^{-2} day^{-1}. The large variation and occasional negative values should be attributed to variation in the samples. Awasa-83 exhibited the highest rate of 9.8 g m^{-2} day^{-1}, and the highest mean crop growth rate of 4.3 g m^{-2} day^{-1} (or 30 g m^{-2} $week^{-1}$) during the tuber-bulking phase. The mean crop growth rate for Bareda and Falaha were 1.8 and 2.8 g m^{-2} day^{-1}, respectively. The mean crop growth rate of 120g m^{-2} $week^{-1}$ reported by Tsuno (1971) was much higher than the mean CGR of 30 g m^{-2} $week^{-1}$ for cultivar Awasa-83. A mean crop growth rate of 20 g m^{-2} day^{-1} (200kg ha^{-1} day^{-1}) is considered acceptable for most crops particularly C_3 types. A mean crop growth rate of 30 g m^{-2} day^{-1} (300 kg ha^{-1} day^{-1} for grain) was reported for C_4 types such as maize (Gardner *et al.*, 1994). Tuber growth rate varied from less than one to more than 6g m^{-2} day^{-1} (0.4t ha^{-1} $week^{-1}$). During the bulking period cultivar Awasa-83 had a mean tuber growth rate of 2.4 g m^{-2} day^{-1}.

Cultivar Bareda and Falaha had tuber growth rates of less than 2g m^{-2} day^{-1}. Enyi (1977) reported that the tuber bulking rates of seven sweet potato cultivars ranged from 50 to 131 g per plant $week^{-1}$ which is equivalent to 22 to 57 g m^{-2} day^{-1}. The mean tuber bulking rate for the three cultivars examined in this study ranged from 12 to 17 g m^{-2} day $^{-1}$ and is much lower compared to the tuber bulking rate values obtained by Enyi (1977). In terms of fresh mass a rate of 2.4 g m^{-2} day^{-1} is equivalent to 0.6t tubers ha^{-1} $week^{-1}$. This clearly emphasizes the importance of maintaining agronomic inputs to optimize yield.

Leaf area duration was calculated for each sampling interval from 90 to 105 days after planting (LAD = average LAI X 15 days). The LAD during the tuber bulking period was 553 days for Awasa-83 and the final yield was 41t ha^{-1} a LAD duration of 495 days for cultivar Falaha was associated with a final yield of 37t ha^{-1}, while for the leaf area duration of 399 days, the final yield of Bareda was 36t ha^{-1}. Enyi (1977) reported that the leaf area duration of seven cultivars he studied ranged from 240 to 616 days and were not correlation with yield.

The NAR was calculated as the net gain of assimilates per unit leaf area per sampling cycle. Large variations in the NAR were recorded which probably reflects the inherent problem of representative sampling. The highest NAR value for cultivar Awasa-83 was recorded during the 120 to 135 days interval. Cultivar Awasa-83 showed the highest net assimilation rate of 4.5 g m^{-2} day^{-1} between 120 and 135 days after planting and the highest mean NAR of 1.9 g m^{-2} day^{-1}. Cultivar Falaha and Bareda showed mean NAR of 1.4 and 1.1 g m^{-2} day^{-1} respectively. At this site values of the mean NAR among cultivars varied from 7.7 to 13.3 g m^{-2} $week^{-1}$, which is much lower than the high values of the NAR of 55 to 60 g m^{-2} $week^{-1}$ reported by Tsuno (1971) for sweet potato.

7.5 CONCLUSIONS

There were differences in dry mass production and partitioning of assimilates to different plant parts between cultivars and among sites. The relative poor growth and yield obtained at Awasa was mainly attributed to low rainfall during the growing season.

The size (LAI), duration (LAD) and efficiency (NAR) of the canopies during the tuber-bulking period play a major role in the final yield. The high yielding cultivars at both sites had larger canopy size (LAI), determining duration (LAD), net assimilation rate (NAR), crop growth rate (CGR) and tuber bulking rate (TBR) which influenced the final yield.

In the case of Falaha the highest fraction of assimilates ranging from 29 to 73 % was partitioned to the storage roots during the growing period. For cultivar Bareda the portion of the dry matter partitioned to the roots increased from 8 to 67 % from 45 to 150 days after planting, while for cultivar Awasa-83 it increased from 4 to 53 %. Although Bareda partitioned less of the available assimilates to storage root growth than Falaha a much higher final yield was produced by the cultivar Bareda at Melkassa.

The variability among cultivars in dry matter production and partitioning suggests that the development of cultivars with higher dry matter production and partitioning to the storage roots is possible. Selection of cultivars for high dry matter production and partitioning should continue, giving more emphasis to multi-locations evaluation to understand how cultivars react to divers agro-ecologies.

Table 7.2 Leaf area index, leaf area duration, net assimilation rate, crop (CGR) and tuber (TGR) growth rates at Awasa

Time	LAI			Cumulative LAD days			NAR g m^{-2} d^{-1}			CGR g m^{-2} d^{-1}			TGR g m^{-2} d^{-1}		
	Aw-83	Bared	Falaha	Aw-83	Bared	Falaha	Aw-83	Bareda	Falaha	Aw-83	Bareda	Falaha	Aw-83	Bareda	Falaha
90 DAP	8.8	2.8	6.1				2.6	-1.4	2.6	4.2	-0.7	2.8	-0.3	0.8	1.5
105 DAP	7.7	8.3	11.1	124	83	133	-0.5	2.8	1.9	-0.7	4.1	3.9	2.6	0.5	0.5
120 DAP	6.6	7.2	5.0	107	116	125	-1.3	3.2	-4.3	-1.5	4.1	-3.9	-2.0	5.2	0.7
135 DAP	12.1	7.2	8.3	140	108	100	4.5	1.9	2.6	9.8	2.4	3.8	5.3	0.9	2.0
150 DAP	12.1	5.0	9.9	182	92	137	4.3	-0.8	4.1	9.5	-0.7	7.4	6.3	1.2	4.3
Total	-	-	-	553	399	495									
Mean	-	-	-				1.9	1.1	1.4	4.3	1.8	2.8	2.4	1.7	1.8

Data not statistically analyzed

7.6 References

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