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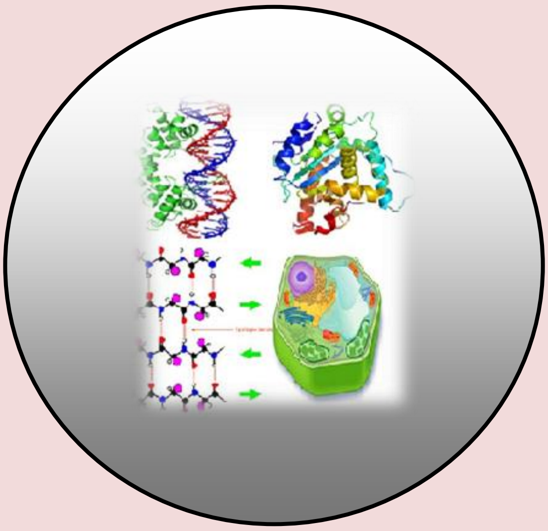

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Effect of Harvest Stages on Yield and Yield Components of Yams (*Dioscorea* spp.) in Southwest Ethiopia

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ABSTRACT

Information on harvest stages on yams is prerequisite for recommendations to growers and food processers. Consequently, the objective of this study was to appraise the effect of different harvest stages on important yield and yield related traits of yams from Southwest Ethiopia. Two landraces, Woko and Welmeka were harvested at six stages at Jimma Agricultural Research Center by using randomized complete block design with three replications. Data on 20 characters from aerial bulbils and storage tubers were collected and subjected to data analyses. The results of the analysis of variance revealed, harvest stages had high significant ($p \leq 0.01$) effect on tip and tuber length, vine and tuber fresh weight, tuber diameter, tuber dry weight, total yield and harvest index. Mean square due to landrace was highly significant ($p \leq 0.01$) for bulbils length, tip length, bulbils fresh weight, tuber diameter, tuber dry weight, total storage tuber yield. Among traits, tip length, tuber diameter, tuber dry weight, total yield, showed significant ($p \leq 0.01$) main effects on landrace and harvest stages. From all traits considered, significant interaction effect was observed between harvest stages and landraces for only tuber diameter. The results indicated there is high possibility for developing best yam landraces for high yield and desirable traits in southwest Ethiopia. At later harvest, increased the number of bulbils plant^{-1}, internodes and tuber length, tuber dry weight and total yield, of yams. While, the value of harvest index decreased significantly in advanced harvest stages in both landraces. Using the overall results, longer harvested yams are produced high yield and related traits than early harvest ones and have positive impacts for food security in southwest Ethiopia.

Keywords: Harvest Stages, Traits, Welmeka, Woko and Yield.

INTRODUCTION

Yam (*Dioscorea* L. spp.) is a multi-species crop that belongs to the genus *Dioscorea* and family *Dioscoreaceae* (Coursey, 1967; Tamiru *et al.*, 2007).

It is found in Africa, India, Southeast Asia, Australia and South America embracing of 600 species (Jayasurya, 1984; Wilkin, 1998; Mignouna *et al*., 2002; Loko *et al*., 2015). All species are tropical origin and cultivated for their edible storage tubers. About ten yam species are cultivated as food staples serving millions of people in the tropics (Hahn, 1993; Sesay *et al*., 2013). West Africa is the predominant yam producing region globally (Tewodros, 2016). The region contributes about 95% of the world's yam produce with considerable varietal and genetic diversity (Hamadina *et al.,* 2009; Dansi *et al.,* 2013).Apart from being staple food, yams are used as medicine to cure various ailments (Choudhary *et al*., 2008; Marcos *et al*., 2014). *Dioscorea bulbifera* is used by tribal ladies as contraceptive and had high contribution by reducing the growing of people currently we face (Schott *et al*., 2000).

Guinea yam (*D. cayenensis* and *D. rotundata* complex) is the most important species in West Africa and represents more than 97% of the total yam production (Mignouna and Dansi, 2003; Dansi *et al*., 2013; Abebe *et al*., 2013; Demuyakor *et al*., 2013). There is considerable varietal and genetic diversity of the *Dioscorea* spp. due to the continuous process of domestication from related and wild species of *D. abyssinica*. *Dioscorea abyssinica* is native to Ethiopia and currently grown in tropical Africa (Rehim and Espig, 1991). *Dioscorea abyssinica* Hochst and *D. praehensili*s Benth are among the wild species which are the progenitors of cultivated yam species in Africa (Hahn, 1995). Ethiopia is an important center of origin and diversity of yam making the country a strategic source of genetic materials for breeding and conservation (Tamiru, 2006; Tewodros, 2016). In Ethiopia, yam has been cultivated in different major growing areas of South and Southwestern parts of the country for different purposes and product forms (Abdissa, 2000; Tewodros, 2013). Yam production in Ethiopia faces various constraints, amongst which are low yields and variable maturity periods that threatens its production and quality. Moreover, different yam species and root crops grown as a sole and mixture of different crops in southwest Ethiopia, however, there is no effort so far done in concerning to the time of harvest (Tewodros and Biruk, 2012). Further, the yield potential of the existed landraces and quality variations between times of harvest across agro-ecological zones have never been assessed, this leads, abridged the yield and quality of the storage tuber and aerial bulbils extensively (Wireko-Manu *et al*., 2013). Besides, the current status of the yield and its variation between species in major growing areas are still unknown. Furthermore, lack of quantitative methods to determining maturity indices makes it difficult for a processor to establish the appropriate harvest stages for quality product (Osagie, 1992; Wireko-Manu *et al*., 2013).Thus, improving productivity and development of quality product is a key to boost yam production in the country (Diby *et al.,* 2009). Therefore, this study was designed to determine the effect of different harvest stages of yams for better yield and related traits in Southwest Ethiopia.

MATERIAL AND METHODS

Study site and plant materials

The study was conducted at Jimma Agricultural Research Center (JARC) during March-December, 2015-2016. The center located at latitude 7^{o} 40.00' N and longitude 36^{o} 47′.00′ E with an altitude of 1753 m.a.s.l. The area received mean annual rainfall of 1432 mm with the maximum and the minimum temperature of 26.5^{0}C and 12.00 ^{0}C, respectively. The soil of the study area is Eutric Nitosol (reddish brown) with p^{H} of 5.3^{5}. Yam landraces namely Woko and Welmeka, which are dominantly grown in Southwest Ethiopia, were harvested at six different months after plant (5, 6, 7, 8, 9 and 10 MAPs) for the study usage.

Experimental design and field establishment

Landraces and harvest stages were laid by using randomized complete block design with three replications as factorial arrangement. The gross plot size of each treatment was 6 m×4 m. Plants spaced 1m×1m between rows and plants, respectively. Bulbils of the same size were used as planting material. All other agronomical practices were followed according to the recommendations and farmer's practices in the area. Each yam plant was tended using dried coffee sticks of 3.5 to 4.5 meter long to provide support and induce good canopy and vine development. Fifteen middle plants were tagged and sampled for data collection and final harvest.

Data collection

Data were collected from fifteen plants during the study according to the descriptors of yam (*Dioscorea* spp.) developed by Bioversity International (IPGRI, 1999), and the average value used for data analysis.

The characters that manifested for data collection are: leaf length (cm), leaf width (cm), petiole length (cm), distance between leaf lobs (cm),vine length (cm), number of bulbils plant^{-1}, bulbils length (cm), bulbils diameter (cm), tuber length (cm), tuber diameter (cm), internodes length (cm), number of internodes vine^{-1}, tip length (cm), vine fresh weight (t/ha), vine dry weight (t/ha), bulbils fresh weight (t/ha), bulbils dry weight (t/ha), tuber fresh weight (t/ha), tuber dry weight (t/ha), total yield (t/ha) and harvest index (%).

Data Analysis

Two- way analysis of variance (ANOVA) was used with months of sampling and landraces as factors for tested traits. The model for the analysis of tested traits at different stages of the harvest as follows: $Y_{ijk} = \mu + H_i + L_j + HL_{ij} + \epsilon_{ijk}$. Where: Y_{ijk}= is the dependent variable, μ is the overall mean; H_i,= the effect of the harvest interval, L_j= the landrace effect, HG_{ij}= the interaction effects of the harvest intervals and landrace and ϵ_{ijk}= the random error, independent and normally distributed. The collected data of yield and related traits were subjected to statistical analysis using the SAS statistical software (SAS, 2000) and mean comparisons among landraces and harvest stages were performed using the least significant difference (LSD) at 1% and 5% levels of significance.

RESULTS

Analysis of variance

The result of the analysis of variance revealed, harvest stages had significant ($p \leq 0.01$) effects on tip and tuber length, vine and tuberfresh weight, tuber diameter, tuber dry weight, total yield and harvest index (Table 1). Mean square due to landrace found to have a highly significant variation ($p \leq 0.01$) for bulbils and tip length, bulbils fresh weight, tuber diameter, tuber dry weight and total yield (Table 1). The interaction effects of landrace and harvest stages hardly showed significant different for all parameters except tuber diameter. From all traits considered, tip length, tuber diameter, tuber dry weight and total yield showed significant variation ($p \leq 0.01$) attributable tomain effect of landrace and harvest stages.

Table 1. Analysis of variance of yield and yield related traits yam landraces grown at Jimma.

Traits	Mean square					
	Rep (DF=2)	MAP (A) (DF=5)	Lan (B) (DF=1)	A*B (DF=5)	Error (DF=22)	CV (%)
Leaf length (cm)	7.79	0.19	0.65	1.81	1.89	8.11
Leaf width (cm)	2.23	0.38	0.73	1.49	1.74	8.48
Petiole length (cm)	19.73	0.80	0.05	0.99	1.03	8.91
Distance between lobs(cm)	7.04	0.04	0.09	0.04	0.11	8.99
Vine length (cm)	7705.6	1291.2*	898.2	572.2	514.3	7.38
Number of vine plant^{-1}	0.37	0.15	0.04	0.15	0.17	21.64
Number of bulbils plant^{-1}	41.45	74.85	37.37	49.57	102.3	15.79
Bulbils length (cm)	0.77	0.35	5.79**	0.87	0.88	9.39
Bulbils diameter (cm)	0.66	0.27	0.23	0.50	0.29	11.84
Internodes length (cm)	8.98	0.81	2.36	0.64	1.05	8.00
Number of internodes vine^{-1}	138.7	40.29	70.84	44.34	121.3	19.48
Tip length (cm)	1.50	0.25**	0.70**	0.08	0.07	7.81
Vine fresh weight (t/ha)	1.52	31.48**	8.01	4.94	2.52	23.25
Bulbils fresh weight (t/ha)	11.07	6.71	72.59**	3.58	7.40	27.82
Tuber length (cm)	2.59	4.88**	1.44	0.91	0.48	7.24
Tuber diameter (cm)	0.15	2.40**	0.90**	1.22**	0.14	4.49
Tuber fresh weight (t/ha)	0.89	19.85**	1.33	0.85	0.78	11.64
Tuber dry weight (t/ha)	0.05	8.48**	1.04**	0.06	0.08	10.72
Total yield (t/ha)	6.47	31.51**	93.54**	5.35	6.74	14.91
Harvest index (%).	34.33	109.47**	9.21	39.91	27.84	7.21

Rep= replication, MAP= Months after Plant, Lan= Landraces and A*B= MAP* Lan, CV= Coefficient of variation

The tested landraces differed in concerning to yield and yield related traits in all investigated harvest stages (Table 1). Consequently, the mean values of yield and yield related components across different harvest stages were used. The mean and coefficient of variation of two landraces (Woko and Welmeka) with important traits and harvest stages are presented in (Table 2). Landraces harvested at 10 MAP had significantly highest vine fresh and dry weight, tuber fresh and dry weight and total yield. On contrary, vine, leaf and petiole length, leaf width, distance between lobs, number of internodes vine^{-1}, internodes length, number of vine hill^{-1}, number of bulbils plant^{-1}, bulbils length, bulbils diameter, bulbils fresh weight and bulbils dry weight were not showed significantly different among harvest stages (Table 2).

Table 2. The mean values of Woko and Welmeka with respective quantitative traits.

Traits	Woko						Mean	CV (%)	LSD -0.01	Welmeka						Mean	CV (%)	LSD -0.01
	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP				5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP			
VL	273	305.9	321.5	286.3	310	315.9	302.1	9.71	53.8	285	331.3	309.1	325.8	306.3	315.3	312	4.42	25.13
LL	16.76	17.14	17.14	16.28	18.28	17.03	17.11	6.58	2.04	17	16.47	16.64	17.69	16.36	16.81	16.8	8.28	2.53
LW	15.21	15.39	15.06	14.89	16.75	15.19	15.42	9.03	2.53	16.1	15.39	15.64	16.28	15.25	15.53	15.7	6.83	1.95
PL	10.56	12.06	11.42	10.88	12.03	11.58	11.42	6.75	1.4	11.3	10.58	11.58	11.5	11.94	11.78	11.4	10.1	2.1
DBL	3.72	3.78	3.94	3.56	3.61	3.67	3.71	8.5	0.57	3.78	3.89	3.83	3.94	3.78	3.67	3.82	9.32	0.64
NVPP	1.89	1.94	1.78	1.94	2.11	2	1.94	13.6	0.48	1.56	1.56	2.06	1.89	2.33	1.83	1.87	24.7	0.84
NBPP	55.39	58.11	56.22	59.72	55.06	63.11	57.94	19.2	22	51.2	55.67	50.33	50.06	55.67	57.89	55.1	11.7	13.82
BL	8.97	8.9	9.89	10.2	9.81	9.76	9.59	8.27	1.44	10.1	10.4	10.1	10.2	10.5	11	10.4	10.9	2.06
BDi	3.42	3.47	3.47	3.18	3.29	3.69	3.42	12	0.98	3.66	4.03	3.46	3.3	3.98	3.78	3.7	11.2	0.94
IL	12.11	12.33	13.52	12.25	12.56	12.72	12.58	6.59	1.5	12.7	12.86	12.82	13.06	13.17	14	13.1	7.42	1.76
NIPV	55.4	58.1	56.2	59.72	63.11	55.05	57.93	14.9	15.7	50.2	55.7	50.33	50.05	57.9	55.7	53.3	21.3	21.34
TiL	3.42	4.85	4.88	4.49	4.42	3.47	4.26	5.23	0.32	3.3	4.42	4.79	4.84	4.09	4.78	4.37	9.94	0.66
VFW	2.8	3.96	7.1	8	8.7	7.5	6.34	10.8	1.25	4.9	4.18	7.85	8.1	7.3	11.4	7.29	29.3	3.49
BFW	6.2	6.6	9.5	10.1	8.4	9.2	8.33	22.7	3.46	9.6	11.8	10.5	11.6	12.1	11.6	11.2	23.6	6.21
TL	7.89	8.44	9.56	9.83	10.11	10.39	9.37	7.85	1.33	8.89	8.89	9.91	9.78	9.61	11.56	9.77	6.55	1.16
TDi	8.06	7.83	9.5	8.56	7.72	8.56	8.37	4.79	0.73	8.28	8.05	9.04	8.72	7.61	9.61	8.55	4.09	0.64
TFW	4.9	5	8.11	8.6	9.1	8.9	7.44	10.5	1.42	6.6	4.8	8.3	9.3	8.7	9.1	7.8	13.4	1.91
TDW	1.19	1.14	2.43	2.8	3.49	3.83	2.48	11.3	0.51	1.65	1.27	2.51	3.11	3.89	4.48	2.82	11	0.56
TY	11.11	14.5	18.2	15.2	17.6	18.1	15.79	12.9	3.72	16.1	16.7	18.8	20.7	20.8	20.9	19	16.2	5.6
HI	79.4	78.6	72	70.6	67	65.4	72.17	5.45	7.21	76.5	80	73.9	72.1	70.6	64.5	72.9	5.82	11.43

VL=Vine length (cm), LL=Leaf length (cm), LW=Leaf width (cm), PL=Petiole length (cm),DBL=Distance between lobs(cm),NVPP=Number of vine plant^{-1},NBPP = Number of bulbils plant^{-1}, BL= Bulbils length (cm), BDi= Bulbils diameter (cm), IL= Internodes length (cm), NIPV= Number of internodes vine^{-1}, TiL= Tip length (cm), VFW= Vine fresh weight (t/ha), BFW= Bulbils fresh weight (t/ha), TL= Tuber length (cm), TDi= Tuber diameter (cm),TFW= Tuber fresh weight (t/ha), TDW= Tuber dry weight (t/ha), TY= Total yield(t/ha) and HI= Harvest index (%). MAP= Months after Plant and CV= Coefficient of Variation

The highest vine length of 321.5 cm and 331.3 cm was harvested at 7 MAP and 6 MAP from Woko and Welmeka, respectively. Number of bulbils per plant ranged from 55.06 to 63.11 and 50.06 to 61.17 from Woko and Welmeka, with a mean of 57.94 and 55.1, respectively. The highest vine fresh weight of 8.70 t/ha harvested at 9 MAP from Woko and ranged from 2.8-8.70 t/ha with a mean of 6.34 t/ha. The higher yielding landrace, Welmeka produced 11.4 t/ha vine fresh weight at 10 MAP and ranged from 4.18-11.4 t/ha with a mean of7.29 t/ha. The highest bulbils fresh weight 10.10 t/ha and 12.10 t/ha was harvested from 8 and 9 MAPs from Woko and Welmeka.

The utmost tuber fresh weight 9.10 t/ha was harvested at 9 MAP and 10 MAP from landraces Woko and Welmeka with a mean of 7.44 and 7.80t/ha, respectively. The highest total yield (20.90 t/ha) was obtained from Welmeka from 10 MAP and ranged from 16.10 to 20.90 t/ha with a mean of 19 t/ha. Similarly, landrace Woko produced 18.10 t/ha tuber yield harvested at 10 MAP with a mean of 15.79 t/ha. The maximum harvest index was 79.4 and 80.0% recorded at 5 MAP and 6 MAPs from landraces Woko and Welmeka, respectively.

DISCUSSION

The result of the analysis of variance revealed, harvest stages had significant ($p \leq 0.01$) effects on most of the traits considered (Table 2). The significant variability among yield and related traits onmain effects of landrace and harvest stages further indicated there isa chance to develop high yielding varieties with variable stages of yam in southwest Ethiopia (Tewodros, 2016).Although, the highest value of vine length of Woko and Welmeka were 321.5 and 331.3 cm harvested at 7 MAP and 6 MAPs, statistically non-significant. Similar results reported by Hirka and Sharma, (1994); Tolera *et al*. (1998) and Sartie *et al.* (2011) who reported there is non-significant ($p \geq 0.05$) difference were observed among harvest stages on vine length, crop residue and total biomass yield onyam and maize. On the contrary, leaf length showed an increasing trend up to 7MAP, whereas most tested traits increased significantly up to 6 MAP and declined at 7 MAP and then increased significantly up to 10 MAP (Table 2). The up and down (undulation) trends when increased harvest stages might be due to the fluctuation of environmental condition in the study area. Likewise, tip and tuber length and tuber diameter were significantly decreased ($p \leq 0.01$) from 6 MAP to 10 MAPs. The decreasing the value of tip and tuber length and tuber diameter in advanced harvest stages is consistent with previous finding of Sartie *et al*. (2011). Further, Hirka and Sharma, (1994) reported, tip length was not affected by harvest stages in maize. According to Njoh *et al.* (2015), leaf and petiole length and leaf width showed greater weight loss at the later harvest due to their rapid drying rate and susceptibility to wind damage on yam.

The value of vine fresh weight ranged from 2.8-8.70 t/ha with a mean of6.34 t/ha. The highest yielding variety Welmeka produced 11.4 t/ha at 10 MAP with ranged from 4.20-11.4 t/ha. The value of vine fresh weight obtained from in this study was consistent with the result of Abong *et al*, (2009) who reported the maximum above ground biomass yield of Irish potato obtained at 120 days after plant. The number of bulbils per plant ranged from 55.06 to 63.11 and 50.06 to 61.17 from Woko and Welmeka. The highest number of bulbils harvested at a later stage (Table 2). The value of bulbils fresh weight ranged from 6.2-10.1 to 9.6-12.1 t/ha with a mean of 10.1 and 12.1 t/ha harvested from 8 and 9 MAPs from Woko and Welmeka, respectively. In most of the characters considered in this study showed small difference with advanced harvest stages in both landraces. At later harvest (9 and 10 MAPs) both landraces produced the highest storage tuber fresh weight (9.1 t/ha) and dry weight (3.83 and 4.48 t/ha). This difference could be explained by the fact that at this stages storage tubers developed well structurally in all aspects, the leaves become yellow, dry well and all bulbils fall down in the ground (Tewodros *et al.* 2012).Similar results were reported by Hagenimana (1996) and Abong *et al.* (2009) who described the dry matter content of sweet potato and Irish potato increased at 120 days after plant. The highest total yield (20.9 t/ha) was obtained from Welmeka at 10 MAP and ranged from 16.10 to 20.90 t/ha. Similarly, the total yield obtained from Woko was 18.1t/ha harvested at 10 MAP with a mean of 15.79 t/ha. In this regards, similar results reported by several other yam studies (Diby*et. al.* 2009; Tewodros, 2012; and Himanshu *et al.,* 2016). In general belief among breeders, at later harvest genotypes produced higher yield than the early harvest, due to as later harvest genotypes have opportunity to draw nutrients and photosynthesize over a longer period (Mesut and Ahmet, 2002; Tewodros, 2016). On contrary, the uppermost value of harvest index 79.4 and 80.0% was obtained at 5 and 6 MAPs in both landraces. This is due to the fact that, at early stage the total yield (bulbils and tuber fresh weight) relatively lower and became un-developed cell structures. In this study, landrace Welmeka showed the highest mean performance in most of the characters that considered in this study than Woko.

CONCLUSION

Harvest stages had significant effects (p≤0.01) on most of agronomical traits considered in this study. Although, the amount of variability in most traits increased up to 6 MAP, significantly highest total yield recorded at 9 MAP and 10 MAPs. This difference is due to the later harvested tuber and bulbils are well developed structurally and physiologically mature in all aspects and have good opportunity to draw nutrients and photosynthesize over a longer time than those harvested early. Succinctly, harvesting of yams between 9MAP to 10 MAP is recommended and more economical to farmers in southwest Ethiopia.

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