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Impact of Stem Removal and Harvesting Date Treatments on Yield and Quality of Cassava Plants

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ABSTRACT

The present study was carried out at the Research Farm of the Environmental Studies & Research Institute, University of Sadat City, Menofiya Governorate, Egypt, during two successive seasons of 2013 and 2014. It was conducted to examine root yield and yield quality under five stem removal treatments i.e., without removal of stem (control),one stem removal, two stems removal, three stems removal and four stems removal with three harvesting date i.e,15thJan., 15th Feb. and 15thMar. The results indicate that significant differences were detected among all used harvest dates, removal of stems and the interactions in all studied traits in both seasons. The earlier harvesting date considered to be the best date of harvesting because it was scored as higher mean values for number of roots/plant, average root weight, moisture content % and total carbohydrates in both seasons and more starch % in 2013. As for stems removal treatments, the treatment of one stems removal considered as the second best treatment after the control because it a gave good means for moisture content in roots during both seasons. Also, it was scored as good values of starch in 2013 and carbohydrates in 2014.The interactions between removal of one stem and the first harvesting date, removal of four stems and first harvesting date, removal of four stems and second harvesting dates as well as removal of four stems and third harvesting date considered as the best treatments among all interactions because it gave highly means in root weight and some qualities measurements. Generally**,** the earlier harvesting date without removal of stem or removal of one stem was found to be the best for Cassava yield and yield qualities. It can be recommended to harvest cassava tuber yield after 10 or 11 months (15th January) from planting without removal of stems, to obtain a high yield of tubers of excellent quality.

Key words: Cassava- stems removal - harvesting date- yield - yield quality.

Introduction

Cassava (*Manihot esculenta* Crantz) is a non-traditional competitive crop, especially for the production of starch, animal feed and alcohol production. Their storage roots have high starch content and can form the major source of various intermediate products including flour, starch and dextrins for food, feed, confectionery, wood, pharmaceutical, adhesives, explosives and other industrial uses. In addition, the storage roots' starches from cassava have some special properties not found in cereal starches. The performance of these products in food, feed and other industries vary according to the crop or variety from which the product was obtained. The variations of the root yield, storage starch and carbohydrates which refer as to differences among cultivars, as well as the harvesting period of the storage roots and farming practice such as stem removal which the farmer use in animal feeding (Jesus *et al.*, 1986; Fukuda and Borges, 1990) and of the canopy (Carvalho *et al.,* 1985; Ravindran, 1993). Cassava should be harvested between 12-15 months after planting. Delaying harvest beyond this age did not result in significant addition to the root yield, instead, promoted bacterial rot especially in TMS 92/0326 cassava variety (Michael *et. al.*, 2015). Increasing the number of cuttings per stand above 2 cuttings per stand resulted in smaller root sizes^{-1}, yields were lower with increasing number of cuttings above two cuttings per stand (Eke-Okoro *et al.,*2010). On the other side, Khuc *et al*., (2012) found that the highest harvesting frequency with the latest harvesting date gave the highest total dry matter foliage production, giving only slightly higher yields compared with the early harvests. The effects of harvesting dates on yield and yield related traits of cassava genotypes were found to be significant with the highest fresh root yield after 18 months from planting. (Tewodros 2012). The clear effects on quantity and quality of foliage and the effect on tuber yield allow alternative foliage harvesting principles depending on the need of fodder for animals, value of tubers and harvesting cost (Duong *et al.,* 2005; Vanthong *et al.,* 2006). Not yield and its components only were affected by harvesting date and stem removal but also the chemical components such as starch and carbohydrates, the reduction observed in the starch content based on the dry matter was not necessarily caused by a direct reduction in the dry matter content in the storage roots (Sales Filho, 1980; Jesus *et al.,* 1986; Fukuda and Borges, 1990).

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Probably, it was caused by the need to hydrolyze the starch stored in the storage roots to low weight carbohydrate molecules to be used in the formation of new sprouts (Madore, 1994). The different harvest intervals of cassava foliage had no major effect on quality, but affected quantity of foliage and root yield (Carvalho *et al.,* 1985, Ravindran, 1993; Hong *et al,* 2003). Moreover, the harvest period had significant effect at 0.05 level on dry matter contents and starch yields. The starch concentration in dry matter of storage roots was reduced by hydrolysis to soluble sugars, but this did not necessarily resulted in a reduction in the dry matter content. The reduction in the starch content, which occurred concomitantly with the rise in sugar concentration in the cassava storage roots has been reported by Ebah-Djedji *et al.* (2012) and Lozano *et al.* (2013). They showed that by using cuttings from plants regenerated after meristem culture, the root and starch yield increased by 69.5 % and 70.3 %, respectively, compared to traditional planting material. Therefore, this study was conducted to elucidate the effect of stems removal and date of harvesting on root yield and its quality of cassava.

Materials and Methods

The present study was carried out at the Research Farm of the Environmental Studies & Research Institute, University of Sadat City, Menofiya Governorate, Egypt, during two successive seasons of 2013 and 2014. The physical and chemical properties of soil and irrigation water are determined according to AOAC (1990) are presented in Tables 1 and 2.

Table 1: The physical and chemical properties of soil.

Physical properties of soil											
Sand %		Silt %		Clay %		Texture					
83		10		7		Sandy loamy					
Chemical properties of soil											
PH	EC dS/m	Soluble salts (mg/100g)									
		Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^{--}	CO_3^{--}	SO_4^-	Moisture %	Organic matter %	CaCO3 %
8.17	1.114	3.3	0.18	1.2	1.2	7.4	1.9	0	3.4	26	0.35	1.7

Table 2: Analysis of irrigation water.

pH	EC dS/m	Soluble Salts (meq/l)								SAR	TDS	Fe ppm	Zn ppm	Mn ppm	Cu ppm
		Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^-						
7.98	1.26	4.2	2.6	6.5	0.2	0	4	7	2.5	3.5	806	0.11	0.18	<0.01	<0.01

SAR = Sodium adsorption ratio. *TDS = Total dissolved solids.*

Cassava was used in the present study to examine root yield and yield quality under five stems or branches removal treatments as follows without removal stems (the control), removal of one stem, removal of two stems, removal of three stems and removal of four stems with three harvesting times i.e., 15thJan (after 10 months), 15thFeb. (after 11 months) and 15thMar (after 12 months) from planting during the two seasons of 2013 and 2014.

The used experimental layout was split plot system in a randomized complete blocks design (RCBD) with three replicates. Each replicate consisted of fifteen treatment combinations, (the combinations among the three harvest dates and the five stems removal treatments). The three harvesting dates were considered as the main plots and the different stem removal treatments were used as the sub - plots. Each experimental unit area was 9.66 $m^{2;}$ including three rows at 2.3 meters long and 1.4m wide, with a plant spacing of half meters between plants.

Stem cuttings were planted at 15th March on one side of the ridge at 50 cm apart with one plant per hill. Plants were fertilized with 250 kg of mono calcium super phosphate add during soil preparation before planting and 300 kg of ammonium sulphate and 200 kg of potassium sulphate per feddan. N and K fertilizers were added at three equal doses after one month, two months and three months from planting. All of the other cultural practices were followed as recommended.

Data were recorded on average of 10 random plants from each experimental plot at harvesting as follows:

Number of roots/plant:
Root diameter:

Roots of random sample of the three plants were taken, and the equatorial wide diameter of root was measured (in cm), using a caliper, then the average roots wide diameter was calculated.

Total yield of roots / plant.
Average root weight.

Total yield of roots/fed. as calculated from plot yield:
Moisture content in roots as a percentage was calculated:

At harvesting stage, roots samples of each treatment were taken immediately and cut off into pieces. Then the samples fresh weight were weighted and oven dried at 70^0 C to constant weight, then the dried samples reweighted and the roots moisture percentage was calculated. Dry weight (g) was measured using an electronic balance (Precisa 125A; Precisa Balances, Switzerland).

Total Carbohydrates

whereas the percentage of carbohydrates in tubers was estimated according to Miller (1959) with DNS method and the concentration was estimated from the calibration standard curve

Starch percentage:

It was calculated as follows:

Starch content = total carbohydrate contents - total soluble sugars content *x* 0.95. (Miller 1959).

Statistical analysis: The data were statistically analyzed by using the method of Wellman, (1998).

Results and Discussion

Number of roots/plant:

Harvesting date effect:

It is clear from the results showing in Table 3 and Fig. 1 that the 3rd harvesting date followed by the 1stharvesting date were the best for number of roots / plant in the both seasons since they gave the highest significant mean value with the average of 11.67 followed by 9.60 in 2013 and 14.53 followed by 10.67 in 2014. On the other side, the 2nd harvesting date was the worst among the three harvesting dates since it showed the lowest means of number of roots /plant in both seasons with average values of 8.83 in 2013 and 10.33 in 2014. These results are in agreement with Michael *et al.* (2015).

Table 3: Effect of stems removal, harvest date and their interaction on number of roots/plant during 2013 and 2014 seasons.

Harvesting dates	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	13.00a	7.33e	13.00a	11.11A	13.67b	8.00g	18.33a	13.33A
One stem	7.67de	8.67cd	11.33b	9.22D	7.00h	11.33de	11.33de	9.89D
2 stems	8.00c-e	10.67b	12.33a	10.33B	11.00e	10.67e	13.00bc	11.56C
3 stems	10.33b	8.33c-e	11.00b	9.89BC	12.33cd	12.33cd	11.33de	12.00BC
4 stems	9.00c	8.67cd	10.67b	9.44CD	9.33f	9.33f	18.67a	12.44B
Mean	9.60B	8.83C	11.67A		10.67B	10.33B	14.53A	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test) small petters for interaction

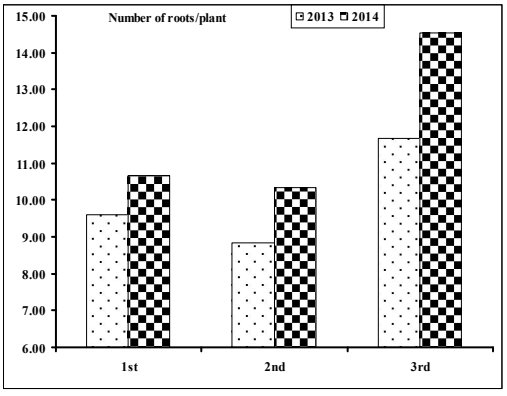

Fig. 1: Effect of harvesting date on number of roots /plant during 2013 and 2014 seasons.

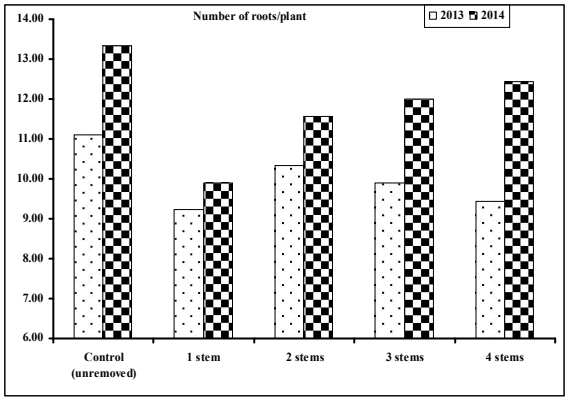

Fig. 2: Effect of stem removal on number of roots / plant during 2013 and 2014 seasons.

Stem removal effect:

From results in Table 3 and Fig. 2 we can detect the significant effect for removal of branches on number of roots/plant compared with the control in both seasons. Meanwhile, the control treatment followed by removal of two stems in the first season showed the highest number of roots/plant among all treatments with averages of

11.11 and 10.33. The two treatments (control) and removal of four stems in the second season gave the highest mean values of number of roots/plant with average of 13.33 and 12.44, respectively. On the other hand, the treatment removal one stem gave the lowest value of number of roots/plant among all treatments in the both seasons with average value of 9.22 and 9.89. Similar results were obtained by Eke-Okoro *et al.* (2010).

The interaction effect:

The results of the effect of the interaction between harvesting dates and removing branches on number of roots/plant showed that the three treatments (control) x 1st harvesting date followed by (control) x 3rd harvesting date and then removal of 2 stems x 3rd harvesting date exhibited the best mean values and differed significantly from all interactions in 2013. On the other side, the three treatments (control) x 3rd harvesting date followed by removal of 4 stems x 3rd harvesting date gave the best mean values and differed significantly from all interactions in 2014. Meanwhile, the interaction between (control) x 2nd harvesting date was the worst in terms of number of roots/plant in both seasons. These results are in contrast with those of Khuc *et al.* (2012).

Through the previous results we can say that the latest date of harvest affect positively the number of roots/plant where it gave a chance for small roots to grow, while the removal of branches affected negatively the number of roots. Since leaves are considered as the factory of the food in plant, those roots lack shoots leads to food shortage transferring to the root, leading to the inability of small roots to grow.

Root wide diameter (cm):

The effect of stems removal, harvesting date and the interaction on root diameter (cm) during the two seasons 2013 and 2014 are presented in Table 4 and Fig. 3 and 4.

Table 4: Effect of stems removal, harvest date and their interactions on root wide diameter (cm) during 2013 and 2014 seasons.

Treatments	Root wide diameter (cm)							
	Harvesting date							
	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	6.27a	3.68e-h	3.20g-i	4.38A	5.77ab	4.17de	4.20de	4.71B
One stem	5.33b	2.58i	4.10d-f	4.01A	5.33bc	4.20de	3.97e	4.50BC
2 stems	4.93bc	3.83e-g	4.00ef	4.25A	6.23a	4.23de	5.23bc	5.23A
3 stems	5.00bc	3.60f-h	4.33c-e	4.31A	5.60ab	4.43de	3.93e	4.66BC
4 stems	5.20b	3.03hi	4.77b-d	4.33A	4.77cd	3.87e	4.23de	4.29C
Mean	5.35A	3.35C	4.08B		5.54A	4.18B	4.31B	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

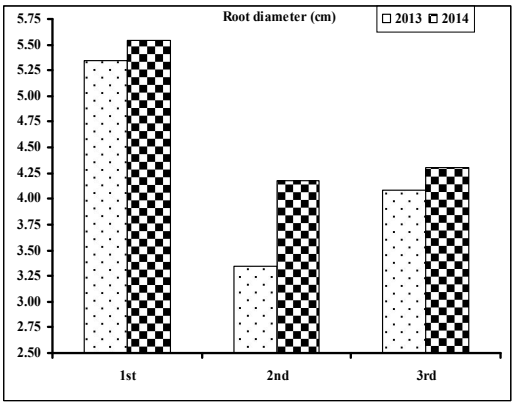

Fig. 3: Effect of harvest date on root wide diameter (cm) during 2013 and 2014 seasons.

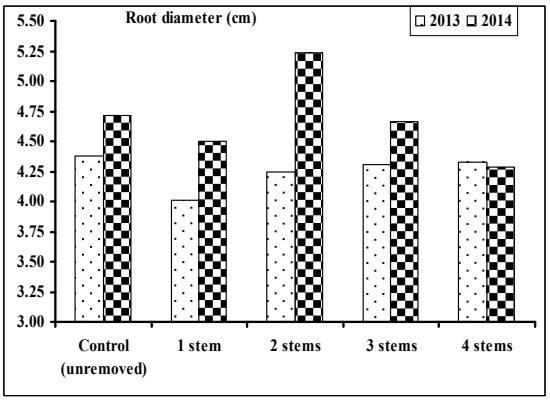

Fig. 4: Effect of stem removal on root wide diameter (cm) during 2013 and 2014 seasons.

Harvesting date effect:

The results shown in Table 4 and fig. 3 indicate that the 1st harvesting date was the best for root wide diameter in the two seasons; it give the highest significant mean value of root wide diameter (cm) with the average of 5.35 cm in 2013 and 5.54 cm in 2014. On the other side, the 2nd harvesting date was the worst among

the three harvesting date it showed the lowest means of root wide diameter in both seasons with average values of 3.35 cm in 2013 and 4.18 cm in 2014 season.

Stem removal effect:

From results in Table 4 and fig. 4 it can be detected the insignificant effect of stems remove at the root wide diameter in 2013 despite the superiority of the control treatment where it give highly mean value but insignificant. Meanwhile removing stems treatments showed significant differences on the root wide diameter. In the second season (2014) the treatment of remove two stems gave the highest value (5.23) for the root wide diameter compared with the other treatments and the control. On the other hand, the treatment of remove 4 stems gave the lowest value of root wide diameter among all treatments in the same season (2014) with average value of 4.29 cm.

The interaction:

The results of the effect of the interaction between harvesting dates and removing branches on root diameter showed that the control treatment x 1st harvesting date followed by the treatment remove one stem x 1stharvesting date gave the best mean values and differed significantly with all interaction in 2013. On the other side, the interaction between the removal of two stems x 1st harvesting date followed by the treatment the control x 1st harvesting date gave the best mean values and differed significantly with all interactions in 2014.

Generally:

it was clear that the first harvesting date combined with the control or removing two stems were the best treatments for root diameter (cm).

Average root weight (g):

Harvesting date effects:

The results shown in Table 5 and Fig. 5 indicate that the second harvesting date followed by the first one in the first season and the first harvesting date followed by the second one in the second season were the best for average root weight (g) in the two seasons it gave the highest significant mean value of root weight (g) with the average of 331.56 followed by 282.99 g in 2013 and 403.83 followed by 262.32 g in 2014. On the other side, the 3ed harvesting date was the worst among the three harvesting date it showed the lowest means of average root weight (g) in both seasons with average values of 200.68 g in 2013 and 188.97 g in 2014. Our results in disagreement with those reported by Tewodros (2012).

Table 5: Effect of stems removal, harvest date and their interactions on average root weight (g) during 2013 and 2014 seasons.

Average root weight (g)								
Harvesting dates								
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	112.31i	379.26d	146.15h	212.57D	245.79f	337.50c	169.12i	250.81C
One stem	425.03c	309.11g	233.89g	322.68B	792.86a	282.44d	262.14e	445.81A
2 stems	275.00e	239.93f	213.30g	242.74C	244.55f	198.69h	248.46f	230.56D
3 stems	140.37h	219.69g	195.45h	185.17E	227.90g	266.83e	185.35hi	226.69D
4 stems	462.22b	509.80a	214.62g	395.55A	508.04b	226.15g	79.81j	271.33B
Mean	282.99B	331.56A	200.68C		403.83A	262.32B	188.97C	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

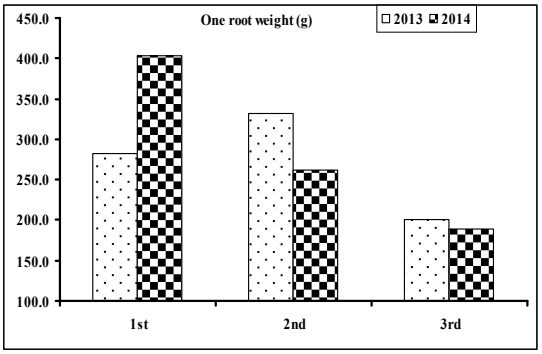

Fig. 5: Effect of harvest date on average root weight (g) during 2013 and 2014 seasons.

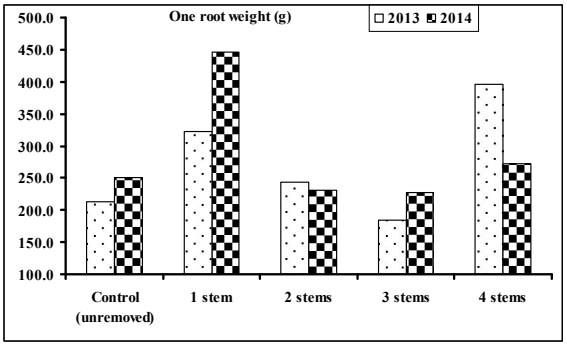

Fig. 6: Effect of stem removal on average root weight (g)during 2013 and 2014 seasons.

Stem removal effect:

with the observation of the effect of the removal of stems on the average root weight (g), it can be seen significant differences between the weights of roots under different removal treatments (Table 5 and Fig. 6). The treatment of removing 4 stems, followed by removing one stems were given the higher values for average root weight with values of 395.55 and 322.68 (g) in 2013 compared with the control. Meanwhile, the treatment removing one stems followed by removing 4 stems give the highest mean values of average root weight more than the control in 2014 with average of 445.81 and 271.33 (g) respectively compared with the control 250.81(g) only. On the other hand, the treatment of removing 3 stems given the lowest value of average root weight among all treatments in the both season with average value of 185.17and 226.69 (g). These results were in harmony with Vanthong *et al*. (2006) and Duong *et al*. (2005). On the other side these results were in contrast with those reported by Essilfie *et al*. (2016).

The interaction:

The results of the effect of the interaction between harvesting dates and removing stems on average root weight show that the treatment of removing 4 stems x second harvesting date followed by the treatment of removing 4 stems x first harvesting date give the best mean values and differed significantly with all interaction in 2013. On the other side, the interaction between removing one stem x 1st harvesting date followed by the treatment of removing 4 stems x 1st harvesting date gave the best mean values and differed significantly with all interaction in 2014.

We can detected that the highly content of water in plant especially in the root but the increasing of remove branches and late of harvesting may be the main reason of loss water from roots and decrease its weights.

Total yield /plant (kg):

Harvesting date effect:

The results clear in Table 6 and Fig. 7 indicate that the second harvesting date in the first season and the first harvesting date in the second season were the best for total yield /plant (kg).

Table 6: Effect of stems removal, harvest date and their interactions on total yield of roots /plant (kg)during 2013 and 2014 seasons.

Total yield /plant (kg)								
Harvesting dates								
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	1.46e	2.78cd	1.90de	2.05CD	3.36b	2.70bc	3.10bc	3.05B
One stem	3.26bc	2.68c-e	2.65c-e	2.86B	5.55a	3.20bc	2.97bc	3.90A
2 stems	2.20c-e	2.56c-e	2.63c-e	2.47BC	2.69bc	2.12cd	3.23bc	2.68B
3 stems	1.45e	1.83de	2.15c-e	1.81D	2.81bc	3.29b	2.10cd	2.74B
4 stems	4.16ab	4.42a	2.29c-e	3.63A	4.74a	2.11cd	1.49d	2.78B
Mean	2.51AB	2.86A	2.33B		3.83A	2.69B	2.58B	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

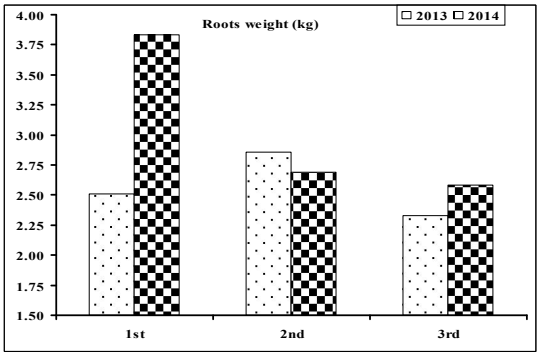

Fig. 7: Effect of harvest date on total yield /plant (kg)during 2013 and 2014 seasons.

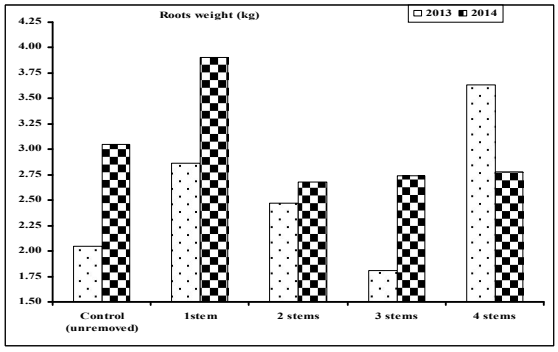

Fig. 8: Effect of stem removal on total yield of roots /plant (kg)during 2013 and 2014 seasons.

It gave the highest significant mean value of total yield /plant (kg) with the average of 2.86 kg in 2013 and 3.83 kg in 2014. On the other side, the 3rd harvesting date was the worst among the three harvesting dates, it showed the lowest means of root weight (kg) in both seasons with average values of 2.33 kg in 2013 and 2.58kg in 2014.

However, no significant differences were noticed among the third harvesting date and the first one in the first season and the second one in the second season of study. Our results are in disagreement with data reported by Tewodros (2012).

Stem removal effect:

With the observation of the effect of the removal of branches on the total yield /plant (kg). Significant differences can be seen between the weight of roots under different removal treatments (Table 6 and Fig. 8). The treatment of removal of 4 stems, followed by removal of one stem had higher averages for total yield /plant (kg) with values of 3.63 and 2.86 in 2013 compared with the control (3.05 kg/plant). Meanwhile, only the treatment of removal of one stem gave the higher mean values of total yield /plant (kg) more than the control in 2014 with on average of 3.90 compared with the control. On the other hand, the treatment removal of 3 stems possessed the lowest value of total yield /plant (kg) among all treatments in the both seasons with average value of 1.81 and 2.74. These results are in harmony with Duong *et al.* (2005) and Vanthong *et al.* (2006). On the other side these results are not agree with those reported by Essilfie *et al.* (2016).

Effect of the interaction:

The results of the effect of the interaction between harvesting dates and removing branches on total yield /plant (kg) show that the treatment of removal of 4 stems x 2nd harvesting date followed by the treatment removal of 4 stems x 1st harvesting date gave the best mean values and differed significantly from all interactions in 2013. On the other side, the interaction between removal of one stem x 1st harvesting date followed by the treatment of removal of 4 stems x 1st harvesting date gave the best mean values and differed significantly from all interactions in 2014.

The high content of water could be detected in plant especially in the root but the late of harvesting may be the main reasons of water loss from roots and decrease its weights.

Total yield of roots (ton)/fed.:

Harvesting date effect:

The results in Table 7 and Fig. 9 indicate that the 2nd harvesting date and 1st harvesting date were the best for total yield of roots (ton/fed.) in the first and second season, respectively.

Table 7: Effect of stems removal, harvest date and their interactions on roots yield (ton / fed.) during 2013 and 2014 seasons.

Total yield of roots (ton)/fed.								
	Harvesting dates							
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	7.78f	16.68bc	11.40ef	12.29D	20.16c	16.21e	18.57c-e	18.31B
One stem	19.35b	16.06cd	15.88cd	17.16B	33.28a	19.20cd	17.80c-e	23.43A
2 stems	13.22c-e	15.38cd	15.80cd	14.80C	16.12e	12.70f	19.40cd	16.07C
3 stems	8.69f	11.00ef	12.89de	10.86D	16.86de	19.76c	12.62f	16.41C
4 stems	24.96a	26.55a	13.75c-e	21.75A	28.45b	12.69f	8.95g	16.70C
Mean	15.04B	17.13A	13.95B		22.97A	16.11B	15.47B	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

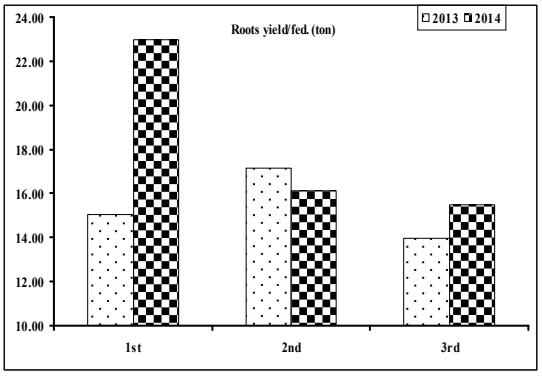

Fig. 9: Effect of harvest date on total yield of roots (ton/ fed.)during 2013 and 2014 seasons.

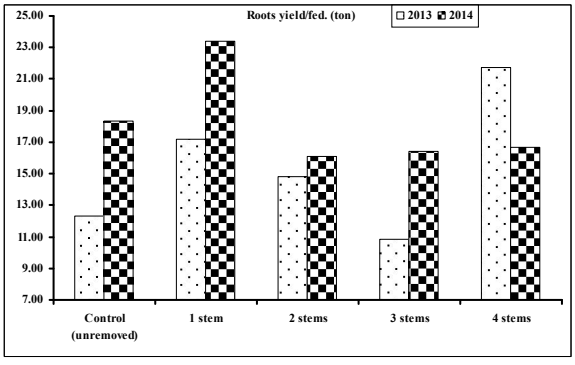

Fig. 10: Effect of stem removal on on total yield of roots (ton/ fed.) during 2013 and 2014 seasons.

It gave the highest mean values of total yield of roots (ton/fed.) with the average of 17.13 tons in 2013 and 22.97 tons in 2014. On the other side, the 3rd harvesting date was the worst among the three harvesting dates since it showed the lowest means of total yield of roots (ton/fed.) in both seasons with average values of 13.94ton in 2013 and 15.47ton in 2014. However, no significant differences were detected among the third harvesting date and the first one in the first season and the second harvesting date in the second season of study. Our results did not agree with those reported by Tewodros (2012).

Stem removal effect:

Concerning the effect of the removal of stems on the total yield of the roots (tons/fed.), there were significant differences between the yield of roots under different removal treatments (Table 7 and Fig. 10). The treatment of removal of 4 stems, followed by removal of one stem were given the higher averages for total yield of roots (tons /fed.) with values of 21.75 tons and 17.16 tons in 2013 season compared with the control. Meanwhile, only the removal one stems gave the highest mean values of total yield than the control in 2014 with average of 23.42 tons compared with control 18.31 tons only. On the other hand, the treatment of removal of 3 stems gave the lowest value of total yield of roots (ton/fed.) among all treatments in the both seasons with average value of 10.86 and 16.07 tons/fed.. These results were in harmony with Duong *et al.* (2005) and Vanthong *et al*. (2006). On the other side, these results disagree with data reported by Essilfie *et al.* (2016).

Effect of the interaction:

The results of the effect of the interaction between harvesting dates and stem removal at total yield of roots (tons/fed.) showed that the removal of 4 stems x 1st harvesting date followed by the removal of 4 stems x 2nd and 1st harvesting date gave the best mean values and differed significantly with all interactions in 2013. On the other side, the interaction between removal of one stem x 1st harvesting date followed by the removal of 4 stems x 1st harvesting date gave the best mean values and differed significantly with all treated interactions in 2014.

Moisture content in roots %:

Harvesting date effect:

It was clear from the results presented in Table 8 and Fig. 11 that the 3rd harvesting date followed by the 1st harvesting date were the best for moisture content of roots in the both seasons since they gave the highest significant mean value with the average of 64.19% followed by 63.14 % of in 2013 and 64.53 % followed by 63.85 % in 2014 season. On the other side, the 2nd harvesting date gave the lowest moisture content of root in both seasons with average values of 61.84 % in 2013 and 62.71 % in 2014 season.

Stem removal effect:

From results in Table 8 and Fig. 12 we can detect the significant effect of stem removal on moisture content of root in both seasons. Meanwhile the treatment of the control without removal of stem showed the highest moisture content of root among all treatments in both seasons with averages of 67.96 % in 2013 and 65.63 % in 2014, respectively. On the other hand, the treatment of removal of four stems gave the lowest value of moisture content of root among all treatments in both seasons with average value of 62.02 % and 62.30 %, respectively. In addition, treatment of removal of two stems in the first season and three stems in the second one rank the second treatments in this respect.

Effect of the interaction:

The results of the effect of the interaction between harvesting dates and stem removing on moisture content of root showed that the three treatments (control) x 1st harvesting date and 3rd harvesting date followed by removal of two stems x 3 harvesting date gave the best mean values and differed significantly with all interactions in 2013 season. On the other side, the treatments of the control x 2nd harvesting date followed by removal of one stem x 3rd harvesting date gave the best mean values and differed significantly from all interactions in 2014 season. Meanwhile, the interaction between removals of four stems x 2ndharvesting date was the worst for moisture content of root in both seasons.

Total Carbohydrates:

Carbohydrate contents are considered as one of the most important determinants of nutritional and economical value of cassava. From the data shown in Table 9 and Figs. 13 and 14 we can conclude the following:

Harvesting date effect:

The 1stharvesting date followed by the 3rdharvesting date gave the best values for total carbohydrates in roots in both seasons, they gave the highest significant mean value with the average of 10.34 (g) followed by

Table 8: Effect of stems removal, harvest date and their interactions on roots moisture content % during 2013 and 2014 seasons.

Moisture content in roots (%)								
Harvesting dates								
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	66.09a	64.43a-c	64.37a-c	64.96A	62.04ef	69.99a	64.57b-d	65.53A
One stem	62.79b-f	61.84c-f	64.78ab	63.14BC	62.69d-f	61.55f	64.89bc	63.04BC
2 stems	63.85a-e	61.68d-f	65.06ab	63.53B	62.39d-f	62.01ef	63.16c-f	62.52C
3 stems	61.42ef	60.20f	62.60b-f	61.41D	64.49b-d	63.96c-e	63.78c-e	64.08B
4 stems	60.88f	61.03f	64.14a-d	62.02CD	62.66d-f	61.02f	66.23b	62.30 C
Mean	63.14B	61.84C	64.19A		63.85B	62.71AB	64.53A	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

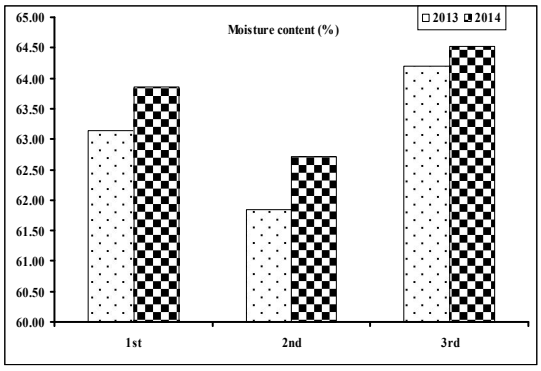

Fig. 11: Effect of harvest date on roots moisture content % during 2013 and 2014 seasons.

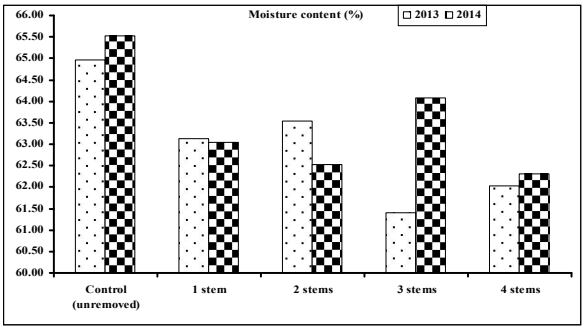

Fig. 12: Effect of stem removal on roots moisture content % during 2013 and 2014 seasons.

Table 9: Effect of stems removal, harvest date and their interactions on total carbohydrates (g/100 g dry matter) during 2013 and 2014 seasons.

Total carbohydrates (g / 100g dry mater)								
Harvesting dates								
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	10.87a-c	7.07g	11.07ab	9.67AB	11.23b	9.23e	10.70b-d	10.39B
One stem	8.90ef	8.67f	10.40b-d	9.32B	11.23b	11.83ab	10.70b-d	11.26A
2 stems	9.63d-f	10.93ab	9.67c-f	10.08A	11.00bc	7.57f	11.37b	9.98B
3 stems	10.47b-d	9.10ef	10.87a-c	10.14A	10.97bc	9.17e	9.57de	9.90B
4 stems	11.83a	10.00b-e	7.43g	9.76AB	9.77c-e	7.23f	12.80a	9.93B
Mean	10.34A	9.15B	9.89AB		10.84A	9.01B	11.03A	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

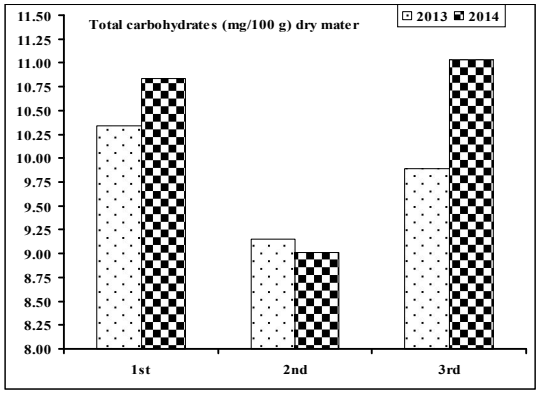

Fig. 13: Effect of harvest date on total carbohydrate (g/ 100g dry mater) during 2013 and 2014 seasons.

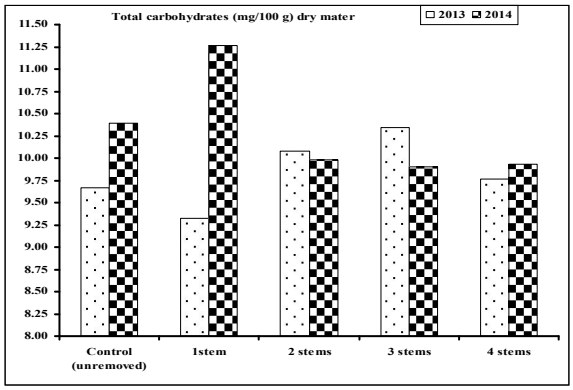

Fig. 14: Effect of stem removal on total carbohydrate (g/100g dry mater) during 2013 and 2014 seasons.

9.89 (g) in 2013 and 10.84 (g) followed by 11.03 (g) in 2014. On the other side, the 2nd harvesting date was the worst among the three harvesting dates since it showed the lowest total carbohydrates of roots in both seasons with average values of 9.15 (g) in 2013 and 9.01 (g) in 2014 season. These results are in agreement with data found by Sales Filho, (1980), Jesus *et al*., (1986) and Fukuda and Borges, (1990)

Stem removal effect:

The treatments of removal of two stems and removal of three stems showed the highest mean values for total carbohydrates compared with the control in 2013 season with averages of 10.08 (g) and 10.14 (g), respectively. Meanwhile, only the treatment removal of one stem showed highest mean value (11.26 g) in the same trait in 2014 compared with the control and other treatments. On the other hand, the treatments of removal of one stem in 2013 and removal of three stems in 2014 gave the lowest value of total carbohydrates among all treatments without significant differences among them in both seasons with average value of 9.32 and 9.90 respectively. These results are in the same trend with those reported by Carvalho *et al.,* (1985), Ravindran, (1993) and Hong *et al* (2003).

Effect of the interaction:

The results of the effect of the interaction between harvesting dates and stems removal on total carbohydrates showed that the removal of four stems x first harvesting date followed by the control x the third harvesting date gave the best mean value and differed significantly from all interactions in 2013. On the other side, the three treatments i.e., removal of four stems x 3rd harvesting date followed by removal of two stem x third harvesting date and then removal of one stem x 1st harvesting date gave the best mean values and differed significantly with all interaction in 2014. Meanwhile the interaction between (control) x 2nd harvesting date in 2013 and removal of four stems x 2nd harvesting date in 2014 were the worst for total carbohydrates.

Starch percentage:

Harvesting date effect:

It was clear from the results detected in Table 10 and Fig. 15 that the 1st harvesting date followed by the 3rd harvesting date were the best for starch percentage in 2013 season. They gave the highest percentages of starch with average of 4.55 and 3.84 respectively. Meanwhile, 2nd harvesting date followed by the 3rd harvesting date had the highest percentage of starch in 2014 season with mean values of 4.53 and 4.06, respectively. On the other side, the 2nd harvesting date in 2013 and the 1st harvesting date in 2014 season were the worst among the three harvesting dates, while they gave the lowest percentage of starch in both seasons with average values of 3.43 and 3.99respectively.This result is in agreement with there is Ebah-Djedji *et al.* (2012).

Stem removal effect:

From results shown in Table 10 and Fig. 16 a significant effect could be traced for stem removal on starch percentage of root in both seasons compared with the control. Meanwhile, the stem removal of one stem followed by removal of two stems showed the highest starch percentage among all treatments in 2013 with averages of 4.75 and 4.56. Meanwhile, the removal of four stems gave the highest percentage of starch more than the control in 2014 season with average of 5.58 %. On the other hand, the removal of three stems gave the lowest value of starch percentage among all treatments in the both seasons with average value of 3.19 and 2.37, respectively. This result is in harmony with that reported by Lozano *et.al.* (2013).

Effect of the interaction:

The results of the effect of the interaction between harvesting dates and stem removal on starch percentage showed that the three treatments removal of two stems x 1st harvesting date followed by removal of one stem x 2nd harvesting date and then the control x 3rd harvesting date gave the best mean values and differed significantly from all interactions in 2013. On the other side, the three treatments of removal of four stems x 3rd harvesting date followed by removal of four stems x 2nd harvesting date and then the control x 2nd harvesting date gave the best mean values and differed significantly from all interaction in 2014. Meanwhile, the interaction between removal of four stems x 2nd harvesting date in 2013 and removal of two stems x 3rd harvesting date in 2014 harvesting date were the worst for starch percentage.

Table 10: Effect of stems removal, harvest date and their interactions on starch % in the root during 2013 and 2014 seasons.

Starch percentage								
Harvesting dates								
Treatments	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean
Stem removal	2013				2014			
Control (unremoved)	4.44a-d	2.22e	5.13ab	3.93B	4.53b-d	5.42b	5.07bc	5.01B
One stem	4.32a-d	5.32a	4.60a-c	4.75A	5.27bc	3.80de	2.03gh	3.70D
2 stems	5.42a	4.53a-d	3.74cd	4.56A	3.77de	4.82bc	4.31cd	4.30C
3 stems	4.06b-d	3.45d	2.28e	3.19C	2.51fg	3.14ef	1.46h	2.37E
4 stems	4.53a-d	1.62e	3.45d	3.20C	3.85de	5.45b	7.44a	5.58A
Mean	4.55A	3.43B	3.84B		3.99B	4.53A	4.06B	

Means in the same column or row with the same small or capital letters are not significantly different at 5% level of probability (Duncan's multiply range test).

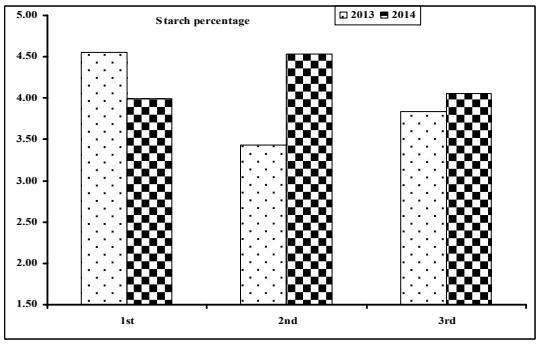

Fig. 15: Effect of harvest date on starch percentage during 2013 and 2014 seasons.

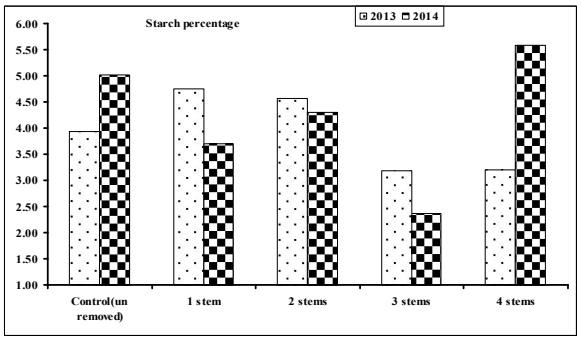

Fig. 16: Effect of stem removal on starch percentage during 2013 and 2014 seasons.

Conclusion

The study concluded that the earliest harvesting date without removal of branch or removal of one branch is the best for cassava yield and yield qualities. It can be recommended to harvest cassava tuber yield of 10 months after transplanting with no unfair removal of vegetative branches, to obtain a high yield of roots with excellent quality.

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