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Effects of Planting Methods on Root Yield and Nutrient Removal of Five Cassava Cultivars Planted in Late Rainy Season in Northeastern Thailand

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Abstract

The objectives of this study were to evaluate growth, yield and nutrients removal of five cassava cultivars planted by different planting methods in late rainy season of northeastern Thailand. A split plot design was used in this study. The planting methods (vertical and horizontal) were assigned as main-plots. Cassava cultivars (Rayong-7, Rayong-11, Rayong-72, Huaybong-80 and E-dum) were assigned as sub-plots with four replications. Results showed that vertical planting gave significantly higher fresh storage root yield than those of horizontal planting, across five cassava cultivars. The cultivar Rayong-7 produced maximum fresh storage root yield across two planting methods, but not significantly different from Rayong 11, Huaybong 80 and Edum cultivars. Irrespective of nutrient removal, N, P and K removed ranges from 2.9 - 3.6, 0.8 - 1.3 and 5.3 - 7.9 kg per ton fresh root weight, respectively depending on cassava cultivar. The cultivar Rayong-7 removed the highest quantities of N, and the cultivar Rayong-11 removed maximum of P and K in the present study. Regardless of nutrient removal at different plant parts; N, P and K removed maximum quantities in leaf, stem and storage root, respectively. Planting method had no significant effect on N and P removal, but significant effect on K removal. The vertical planting removed K higher than those of horizontal planting.

Keywords

Cassava Cultivar, Planting Method, Root Yield, Nutrient Removal, Drought

1. Introduction

Cassava (*Manihot esculenta* Crantz) has been recognized as one of the most important subsidiary cash crops in northeastern Thailand. The average total area planted to the crop and production of cassava per annum in northeastern Thailand is 0.74 million hectares and 15.9 million tones, respectively [1]. Cassava is mostly propagated vegetatively by stem cutting, the quality and cutting size are of importance for obtaining greater yields in any productive systems, and the other most important practice in cassava production is the planting method of stem cuttings at planting which depends on plant cultivar and environmental conditions [2]. There are three different planting methods usually used in the field. It may be planted uprightly in a vertical position, uprightly at an angle (slant) or horizontally beneath the soil. Tuber yield was higher in the vertical and inclined plantings compared to horizontal method [3]. Planting method did not have significant effect on growth and yield of cassava [4]. Cassava planting time usually takes place at the late of the rainy season starting from October to November, and root yield can be harvested after being grown for 8 - 12 months. In general, cassava storage roots contain relative large amounts of K [5]. Tuber yield removed N ranges 193 - 222, P ranges 23 - 25 and K ranges 181 - 218 kg ha^{-1} respectively, depending on type of organic manures application [6]. Therefore the objectives of this research were to evaluate the effect of planting method on growth, yield and nutrient removal of five cassava cultivars planted in late rainy season of northeastern Thailand.

2. Materials and Methods

2.1. Experimental Site

A field experiment was carried out at the Faculty of Agriculture Farm, Khon Kaen University (latitude 16˚28'N, longitude 120˚48'E, 200 m a.s.l) in 2014-2015. The planting date was December 18th, and the crops were harvested 300 days after planting (DAP). The soil texture of the experimental area is loamy sand with 6.6 pH, 0.19% total N, 38.11 mg·kg^{-1} available P, and 40.2 mg·kg^{-1} exchangeable K. The field capacity (FC) and permanent wilting point (PWP) of the soil were 13.2% and 2.8%, respectively.

2.2. Experimental Design and Plant Culture

The split plot design with four replications was used in this study. Two planting methods; vertical planting (stem cutting inserted into the soil forming 90˚ angles on top of ridges) and horizontal planting (stem cutting forming 180˚ angles with soil surface placed in furrow was assigned as main-plot) and five cassava cultivars (Rayong-7, Rayong-11, Rayong-72, Huaybong-80 and E-dum) were assigned as sub-plots. A four-wheel tractor was used to prepare the land by plowing twice, and creating ridges. The distance between rows and plant of cassava was about 1 × 1 m, and the ridge height was about 0.4 m. The mature stems were cut about 15 cm long and vertical planting inserted into moist soil with two-

thirds of the length on top of the ridges. In case of horizontal planting, the stem cutting was horizontally placed in furrows made by hand hoes on top of the ridges to the depth of 10 cm and fully covered by soil. Chemical fertilizer formula 15-15-15 (N, P_2O_5, K_2O) at rate of 312 kg·ha^{-1} was applied one month after planting. Hand weeding was done once before fertilizer application. Pesticides were not used throughout the growing period. Water was applied once with sprinkler irrigation at 7 DAP to provide good crop germination. Thereafter, the crop received only rainfall until harvest (Table 1). In the present experiment, cassava experienced water stress at 45 DAP for 60 days during the cropping season (Figure 1).

2.3. Crop Measurements

Data on adventitious root dry weight was measured at 45 DAP. Above ground dry weight was recorded at 45, 110, 210 and 300 DAP. The number of storage roots per plant, weight of storage roots per plant and fresh storage root yield were determined at 300 DAP in the harvesting area of each plot. The contents of starch in storages root were measured by specific gravity method. The harvest index was calculated from storage roots dry matter divided by total dry matter. Leaf samples were taken during the drought phase at 60, 80 and 110 DAP outside the harvesting area to determine relative water content (RWC). Three leaves of the fourth fully-expanded from the top of each plant within plot were sampled, and twenty leaf disks (1.5 × 2.0 cm, wide × long) were excised from the

Table 1. Weather data of the experimental site during cropping season.

Month	Temperature (˚C)		Rainfall	ET	RH	Sunshine
	Maximum	Minimum	(mm)	(mm·day^{-1})	(%)	(h·day^{-1})
Year 2013						
December	27.5	14.5	26.2	4.63	86	8.27
Year 2014						
January	29.7	13.7	0	4.91	84	9.04
February	33.4	19.2	0	5.37	81	7.78
March	36.6	23.4	2.7	6.25	82	8.02
April	35.6	24.6	164.2	5.49	87	7.55
May	35.9	24.9	75.7	5.49	87	8.04
June	35.3	25.8	102.1	5.61	86	6.46
July	32.7	24.7	188.9	4.46	90	3.20
August	32.9	24.3	209.2	4.33	91	4.33
September	32.5	23.9	155.9	4.09	90	4.86
October	29.8	22.9	50.7	4.21	84	7.69

ET = pan evaporation, RH = relative humidity.

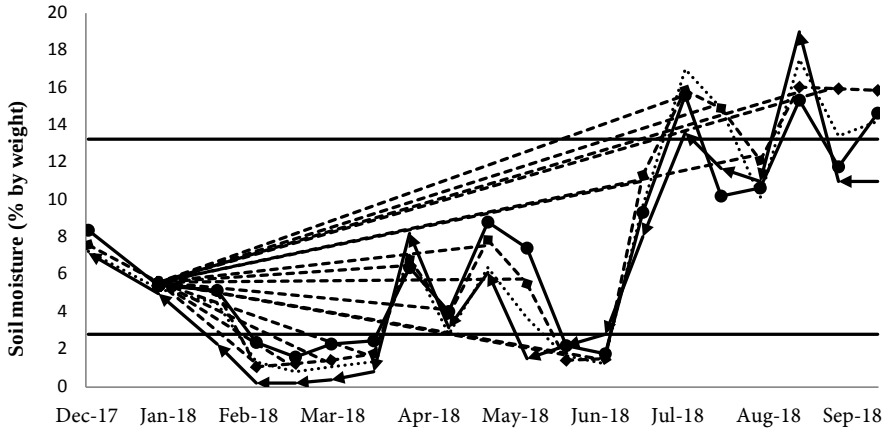

Figure 1. Soil moisture content (%) at soil depth 0 - 15 cm (←), 15 - 30 cm (——), 30 - 45 cm (◆-◆) and 45 - 60 cm (●-●) entire growing periods.

middle of center lobe (avoiding the midrib) weighed and placed in a petri dish of distilled water for 4 hours, re-weighed to determine hydration weight (HW), and then dried at 60˚C for 48 hours for dry weight (DW) determination, RWC was then calculated by dividing the difference between fresh weight and dry weight by the difference between HW and DW [7]. Dropping leaves were collected three times during the cropping season with sampled areas of 2 × 6 meter from each plot outside harvesting area. Thereafter, leaf samples were dried at 60° for 48 hours for dry weight determination.

2.4. Nutrient Removal and Supplying

Dry matter harvests and samples for plant nutrient analysis such as leaf, stem and storage root were collected at 300 DAP. Samples of stems were collected from the middle one-third of three plants, and root samples were obtained from four randomly selected medium sized storage roots. Leaves were collected from the entire plant. Samples were dried at 60˚C, ground and analyzed for total N, total P and total K concentration. Nitrogen concentration was measured by micro kjeldahl method, P concentration by emission spectrophotometer and K concentration by emission flame photometer. Nitrogen, phosphorus and potassium uptake were calculated by multiplying the quantity of dry matter for plants part with nutrient concentration. Regardless of nutrient returning, the dropping leaves were collected three times during the cropping season with sampled areas of 2 × 6 meter from each plot outside harvesting area. The nutrient concentration and uptake were measured as the same procedures with nutrient removal.

2.5. Climatic and Soil Moisture Measurements

The weather data was recorded in an open field at a distance of 350 m from the experimental field. The values of air temperature (maximum and minimum), relative humidity, incoming sun light, pan evaporation and rainfall are shown in Table 1. The soil moisture content was determined by gravimetric measurement at 0 - 15, 15-30 and 30 - 45 cm depth 15 days interval (Figure 1).

3. Results

3.1. Above Ground and Adventitious Root Dry Weight

Planting methods did not have significant effect on above ground dry weight (AGDW) at 45, 110, 210 and 300 days after planting (DAP), as well as adventitious root dry weight (ARDW) at 45 DAP (Table 2). However, vertical planting tends to give higher AGDW at all growth stages and ARDW at 45 DAP. Irrespective of cassava cultivar, the data shows that cassava cultivar had significant effect on ADGW at 110, 210 and 300 DAP, but did not effect at 45 DAP (Table 2).

The cultivar HB-80 gave the highest AGDW at 110, 210 and 300 DAP. The ARDW had significant effect with respect to cassava cultivars (Table 2). The cultivar RY-7 gave the highest ARDW in the present study. There was an interactive effect between planting method and cassava cultivar on AGDW at 110 and 300 DAP. The cultivar HB-80 gave the highest AGDW with vertical planting, while RY-11 gave the maximum AGDW with horizontal planting at 110 DAP. Further, the cultivar HB-80 gave the highest AGDW with vertical planting, while cultivar RY-7 gave the maximum AGDW with horizontal planting at 300 DAP (data not shown).

3.2. Root Yield, Yield Components, Starch Quality and Harvest Index

Planting methods had significant effects on the number of storage roots per

Table 2. Effect of planting methods on above ground dry weight at 45, 110, 210 and 300 days after planting (DAP) and adventitious root dry weight (ARDW) at 45 DAP of five cassava cultivars.

Treatment	Above ground dry weight (gm·plant^{-1})				ARDW (gm·plant^{-1})
	45	110	210	300	
	DAP				
Planting method (M)					
Vertical	6.9	183.8	851.5	1059.1	0.67
Horizontal	6.6	167.6	752.3	867.2	0.66
Cultivar (C)					
Rayong-7	7.2	178.2 a	1052.5 a	946.9 b	0.88 a
Rayong-11	6.6	223.4 a	534.0 b	937.1 b	0.71 ab
Rayong-72	5.3	116.0 b	502.5 b	592.0 c	0.46 b
Huaybong-80	7.4	185.7 a	994.6 a	1195.1 a	0.47 b
E-dum	7.6.	175.4 a	952.8 a	1144.0 ab	0.80 a
F-test					
M	ns	ns	ns	ns	ns
C	ns	*	**	**	*
M × C	ns	*	ns	**	ns

*, ** and ns = Significant at 0.05 level, significant at 0.01 level and not significant, respectively. Means in the same column with different letters are significantly different at $p \leq 0.05$ and $p \leq 0.01$, as determined by LSD.

plant and fresh storage root yield, but not significant effect on weight of storage roots per plant, starch content and harvest index (Table 3). Vertical planting produced the maximum number of storage roots per plant and fresh storage root yields in the present study. Irrespective of cultivar, the data shows that cassava cultivar had significant effect on the number of storage roots per plant, weight of storage roots per plant, fresh storage root yield, starch content and harvest index (Table 3). The cultivar RY-11 gave the highest number of storage roots per plant. While, cultivar RY-7 produced the maximum weight of storage roots per plant and fresh storage root yield. Regardless of starch content and harvest index, cultivar HB-80 exhibited the highest starch content in storage roots. Whereas, cultivar RY-72 illustrated the maximum harvest index value (Table 3). There was an interactive effect between planting method and cassava cultivar on starch content. The cultivar RY-11 produced the highest the starch content with vertical planting, while the cultivar HB-80 gave the maximum starch content with horizontal planting (data not shown).

3.3. Dropping Leaf and Relative Water Content

Planting method and cassava cultivar had significant effects on dropping leaf dry weight (DLDW) (Table 4). The maximum DLDW was obtained by vertical planting. Regardless of cassava cultivar, the data shows that HB-80 gave the highest DLDW (Table 4). In the present study, there was an interactive effect between planting methods and cultivar on DLDW. The cultivar HB-80 gave the highest DLDW with vertical planting, while cultivar RY-7 provided the highest

Table 3. Effect of planting methods on number of storage root per plant, weight of storage root per plant, fresh storage root yield, harvest index and starch content of five cassava cultivars at harvest.

Treatment	Number of storage root per plant	Weight of storage root per plant (kg)	Fresh storage root yield ($t \cdot ha^{-1}$)	Starch content (%)	Harvest index
Planting method (M)					
Vertical	10.7 a	6.1	60.6 a	28.1	0.74
Horizontal	8.9 b	5.3	54.3 b	27.8	0.77
Cultivar (C)					
Rayong-7	10.3 a	6.7 a	67.4 a	28.5 ab	0.78 ab
Rayong-11	10.8 a	5.4 ab	54.6 ab	28.9 a	0.75 bc
Rayong-72	7.7 b	5.3 ab	49.7 b	26.4 b	0.81 a
Huaybong-80	10.1 ab	4.8 b	55.0 ab	29.4 a	0.70 c
E-dum	10.2 a	6.1 ab	60.4 ab	26.6 b	0.72 c
F-test					
M	*	ns	*	ns	ns
C	*	*	*	*	**
M × C	ns	ns	ns	*	ns

*, ** and ns = Significant at 0.05 level, significant at 0.01 level and not significant, respectively. Means in the same column with different letters are significantly different at $p \leq 0.05$ and $p \leq 0.01$, as determined by LSD.

Table 4. Effect of planting methods on dropping leaf entire cropping season and relative water content at 60, 80 and 110 days after planting (DAP) during drought period of five cassava cultivars.

Treatment	Dropping leaf		Relative water content (%)		
	Dry weight ($t \cdot ha^{-1}$)	Percentage[A]	60	80	110
			DAP		
Planting method (M)					
Vertical	1.88 a	44.9	87.5	81.0 b	89.6
Horizontal	1.48 b	41.9	85.6	58.7 a	89.4
Cultivar (C)					
Rayong-7	1.78 a	46.7 a	87.1	82.6	88.4
Rayong-11	1.78 a	44.2 a	87.1	84.8	89.1
Rayong-72	1.61 ab	46.4 a	84.7	81.8	90.3
Huaybong-80	1.92 a	47.2 a	86.1	82.5	90.5
E-dum	1.33 b	32.4 b	87.9	85.1	89.1
F-test					
M	**	ns	ns	*	ns
C	*	*	ns	ns	ns
M × C	*	ns	ns	ns	ns

*, ** and ns = Significant at 0.05 level, significant at 0.01 level and not significant, respectively. Means in the same column with different letters are significantly different at $p \leq 0.05$ and $p \leq 0.01$, as determined by LSD; [A]Percentage of dropping leaf dry weight to total leaf dry weight (dropped leaf + retained leaf on plant.

dropping leaf dry weight with horizontal planting (data not shown). Planting method did not have significant effects on dropping leaf percentage, but had significant effects among cassava cultivars (Table 4). The cultivar HB-80 gave maximum dropping leaf percentage in the present study. Regardless of relative water content (RWC), planting method did not have significant effects on RWC at 60 and 110 DAP, but significant effect on RWC at 80 DAP (Table 4). Horizontal planting gave higher RWC value than those of vertical planting. Irrespective of cultivar, the data shows that cassava cultivars had no significant effect on RWC in the present study (Table 4).

3.4. Nutrient Uptake of Different Plant Part

Planting methods and cassava cultivars had significant effects on nitrogen uptake of storage roots, but not significant effect on nitrogen uptake of stem and leaf (Table 5). The vertical planting and cultivar RY-7 gave the maximum nitrogen uptake in the present experiment. There was an interactive effect between planting method and cassava cultivar on N uptake of stem. The cultivar HB-80 gave the highest N uptake of stem from vertical planting, while RY-7 exhibited the highest N uptake of stem from horizontal planting. Again, there was an interactive effect between planting methods and cassava cultivar on N uptake of leaf. The cultivar RY-11 illustrated the maximum N uptake of leaf from vertical planting, while cultivar RY-7 gave the highest N uptake of leaf from horizontal

Table 5. Effect of planting methods on nitrogen, phosphorus and potassium uptake by storage root, stem and leaf of five cassava cultivars at harvest.

Treatment	Nitrogen (kg·ha^{-1})			Phosphorus (kg·ha^{-1})			Potassium (kg·ha^{-1})		
	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf
Planting method (M)									
Vertical	60.1 a	47.0	88.8	25.3 a	28.3	7.9	273.8 a	73.8	30.1
Horizontal	54.3 b	38.9	80.2	22.6 b	24.2	7.1	249.6 b	73.6	28.2
Cultivar (C)									
Rayong-7	74.7 a	45.3	85.5	27.9	35.8 a	6.9 ab	316.0	54.7 b	35.7 a
Rayong-11	59.9 ab	38.8	95.9	25.4	37.1 a	9.2 a	283.8	111.1 a	33.9 ab
Rayong-72	45.9 b	38.8	74.1	20.7	19.0 b	6.5 b	223.4	58.8 a	24.3 c
Huaybong-80	55.6 b	48.5	72.1	22.1	21.0 b	5.6 b	227.0	96.2 a	25.3 bc
E-dum	49.9 b	41.1	94.8	23.4	18.4 b	9.0 a	258.1	48.2 b	26.2 bc
F-test									
M	*	ns	ns	**	ns	ns	*	ns	ns
C	*	ns	ns	ns	**	*	ns	**	*
M × C	ns	*	*	ns	*	*	*	ns	**

*, ** and ns = Significant at 0.05 level, significant at 0.01 level and not significant, respectively. Means in the same column with different letters are significantly different at $p \leq 0.05$ and $p \leq 0.01$, as determined by LSD.

planting. Irrespective of phosphorus, the data shows that planting method had significant effects on phosphorus uptake of storage roots, but not significant effect on phosphorus uptake of stem and leaf (Table 5). The vertical planting gave the highest phosphorus uptake in the present study. The cassava cultivar had significant effects on phosphorus uptake of stem and leaf, but not significant effects on storage roots. The cultivar RY-11 exhibited the highest phosphorus uptake of stem and leaf in the present study. There was an interactive effect between planting method and cassava cultivar on P uptake of stem and leaf. The cultivar RY-11 gave the highest P uptake of stem and leaf from vertical planting, while cultivar RY-7 exhibited the highest P uptake of stem and leaf from horizontal planting. Regardless of potassium uptake, the data showed that planting method did not have significant effect on potassium uptake of stem and leaf, but significant differences on roots of cassava (Table 5). Vertical planting method gave higher potassium uptake than those of horizontal planting. The cassava cultivar had significant effects on potassium uptake of stem and leaf, but not significant difference on root (Table 5). The cassava RY-11 illustrated the highest potassium uptake of stem, while cultivar RY-7 exhibited maximum potassium uptake of leaf in this study. There was an interactive effect between planting method and cassava cultivar on K uptake of leaf and root. The cassava RY-11 gave the highest K uptake of leaf and root from vertical planting, while cultivar RY-7 illustrated maximum K uptake of leaf and root from horizontal planting (data not shown).

3.5. Nutrient Removal and Returning

Planting methods did not have significant effects on N and P removal of cassava but showed significant effects on K removal (Table 6). Vertical planting removed K quantities in root greater than horizontal planting. Cassava cultivar had significant effects on P removal, but not significant effect on N and K removal (Table 6). The cultivar RY-11 removed the highest P in the present study. There was an interactive effect between planting method and cassava cultivar on N and K removal. The cassava RY-11 removed the maximum quantities of N and K with vertical planting, while cultivar RY-7 removed the highest quantities of N and K with horizontal planting (data not shown). Regardless of nutrient returning, the data shows that planting methods had significant effects on N, P and K returning into the soil in the present experiment (Table 6). Vertical planting returned N, P and K greater than horizontal planting. Cassava cultivars had significant effects on P removal, but not significant effects on N and K removal (Table 6). The cultivar RY-11 removed the greatest quantity P in the present experiment. Irrespective of nutrient returning, cassava cultivar had significant effects on N and K returning, but not significant effect on P returning into the soil in the present experiment (Table 6). The cassava RY-11 gave the highest of N and K returning into the soil in this study. There was an interactive effect between planting method and cassava cultivar on N and P returning. The cultivar RY-11 gave maximum N returning with vertical planting, while E-dum cultivar gave the highest N returning with horizontal planting. Regardless of P

Table 6. Effect of planting methods on nitrogen, phosphorus and potassium removed in the harvest products and returned into the soil by dropping leaves of five cassava cultivars.

Treatment	Nitrogen (kg·ha^{-1})		Phosphorus (kg·ha^{-1})		Potassium (kg·ha^{-1})	
	Removed^{A}	Returned^{B}	Removed^{A}	Returned^{B}	Removed^{A}	Returned^{B}
Planting method (M)						
Vertical	195.8	18.2 a	61.5	3.8 a	377.7 a	5.0 a
Horizontal	172.6	15.3 b	53.9	3.1 b	342.6 b	3.9 b
Cultivar (C)						
Rayong-7	205.4	18.6 a	70.7 a	3.5	396.9	4.2 b
Rayong-11	194.7	19.2 a	71.6 a	3.2	428.9	5.8 a
Rayong-72	158.9	14.1 b	46.2 b	3.5	306.5	3.8 b
Huaybong-80	176.2	13.4 b	48.7 b	3.2	348.5	5.7 a
E-dum	176.1	18.4 a	51.2 b	3.5	320.5	2.7 c
F-test						
M	ns	**	ns	**	*	*
C	ns	**	**	ns	ns	**
M × C	*	**	ns	*	*	ns

*, ** and ns = Significant at 0.05 level, significant at 0.01 level and not significant, respectively. Means in the same column with different letters are significantly different at $p \leq 0.05$ and $p \leq 0.01$, as determined by LSD; ^{A}N-removed in storage root, stem and leaf (uptake) at harvest; ^{B}N-returned in dropping leaf (uptake) into the soil during cropping season.

returning, cultivar HB-80 gave maximum P returning with vertical planting, while cultivar E-dum gave the highest P returning with horizontal planting method (data not shown).

4. Discussion

4.1. Growth and Yield

Vertical planting gave significantly higher fresh storage root yields than those of horizontal planting method. This was due to the fact that vertical planting produced higher above ground biomass. The present findings are in agreement with those of several investigators [8] [9] [10].

The results of the vertical planting gave significantly higher number of storage roots per plant than those of horizontal planting. In contrast, vertical and horizontal planting methods did not show any significant effects with respect to number of storage roots per plant [9]. In the present experiment, vertical planting out-yielded the horizontal planting. Similar results agree with previous reported [9] [11] [12]. In contrast, planting methods had no effect on the root yields of cassava as previously reported [4] [13] [14]. Irrespective of cassava cultivar, RY-7 produced significantly higher storage root yields than those of RY-72, but had no significant effect with RY-11, HB-80 and E-dum cultivars. This was due to the fact that the RY-7 associated with the highest number of storage roots and weight of storage roots per plant. In the present experiment, drought occurred at 45 DAP for 60 days. Cassava is regarded as a relatively drought resistant crop. During drought, it reduces water use by leaf area reduction [15] [16] and stomatal closure [17] [18] [19]. In the present study, leaf relative water content (RWC) did not show significant differences among cultivars at 60 and 80 DAP during the drought period and at 110 DAP in the recovery phase. This indicated that all cultivars were similarly capable of maintaining leaf turgor under drought period. However, we have observed that cultivar RY-7 and E-dum which produced higher storage root yields than those of other cultivars exhibited higher adventitious roots dry weight during their establishment period before entering the drought period.

4.2. Harvest Index and Starch Content

In the present experiment, vertical and horizontal planting did not show any significant effects on harvest index (HI). This contrasts with previous studies, vertical planting showed significantly higher HI than those of horizontal planting [9]. Irrespective of cassava cultivar, RY-72 gave higher HI, indicating that it was highly efficient in translocation of assimilates for storage in tuber roots. In the present study, vertical and horizontal planting did not illustrate significant effects on the starch content (SC) in storage roots. This contrasts with previous studies where, vertical planting exhibited significant higher SC than those of horizontal planting [12]. Regardless of cassava cultivar, SC was significantly different among cultivars. The cultivar Huaybong-80 gave maximum starch content in storage roots. Such cultivars were characterized as having high starch content in

storage roots [20].

4.3. Nutrient Removal

At harvest, cassava had removed the greatest quantities of N in the leaf, the stem and K in the storage roots. Similar results were observed for N, P and K removal quantities as reported by [21]. Cassava had removed maximum quantities of N and P in the stem and K in the storage root was reported by [22]. Regardless of planting methods, vertical planting had removed higher N, P and K quantities than those of horizontal planting. This was mainly due to the fact that the vertical planting associated with greater above ground biomass and storage root yields at harvest. Cassava removed the greatest quantities of K as compared to N and P in this study. N removed per ton fresh storage root weight at harvest ranges from 2.9 - 3.6 kg, 0.85 - 1.31 kg for P and 5.3 - 7.9 kg for K, depending on cassava cultivars. K removed from 3 to 5 kg per ton fresh storage root was reported by [23].

5. Conclusion

Cassava was planted in October, in late rainy season, and the crop experienced drought in February-March for 45 days. Vertical planting methods produced the fresh storage root yields (60.6 $t \cdot ha^{-1}$) significantly higher than those of horizontal planting (54.3 $t \cdot ha^{-1}$) in the present experiment. The storage root yields range from 49.7 - 67.4 $t \cdot ha^{-1}$, depending on the cassava cultivars. The cassava cultivar RY-7 gave maximum fresh storage root yields in the present study. Irrespective of nutrient removal, vertical planting removed N, P and K higher than those of horizontal planting. N removal ranges from 159 - 205 kg, 46 - 72 kg for P and 307 - 429 kg for K per hectare, depending on cassava cultivar. Regardless of nutrient removal in plant part, N removed maximum quantities in the leaf, P in the stem and K in the storage roots in the present experiment.

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