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Original Research Article

Growth and yield of turmeric in a derived savanna agro-ecology of Nigeria

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Fifteen turmeric accessions were evaluated during the rainy season of 2012 and 2013 at Igbariam (6.4°N, 6.93°E) in order to identify and select high yielding genotypes suitable for production in derived savanna zone of Nigeria. The accessions were laid out in randomized complete block design (RCBD) in three replications. Results obtained indicate that plant emergence was generally high ranging from 85 - 100%. Girth of main stem, plant height, tillering, number of leaves and leaf area increased with time and there were significant differences between turmeric accessions in these attributes at most sampling dates. Number of mother rhizome ranged from 23.7 in UT39 to 34.2 in UT35; while number of primary rhizome ranged from 64.7 in UT39 to 98.4 in UT35, number of secondary rhizome ranged from 189 in UT41 to 364.4 in UT25. The mean number of mother rhizome produced in 2012 was significantly higher than the number produced in 2013 but the mean number of primary and secondary rhizome produced in both years did not differ. The weight of mother and secondary rhizome sand total rhizome yield varied significantly with accession ranging from 0.55kg/m² in UT60 to 1.45 kg/m² inUT41; 0.85 kg/m² in UT16 to 1.50 kg/m² in UT39; and 2.15 kg/m² in UT16 to 4.15 kg/m² in UT39 respectively. UT39 with the highest total rhizome yield did not differ from 10 other accessions in this attribute. In general, high total rhizome yield (2.15 – 4.15kg/m2) and the large numbers of secondary rhizome recorded are indicative of the suitability of derived savanna agro-ecology for commercial production of turmeric in Nigeria; however, further study is suggested to cover more locations.

Key words: Curcuma longa, accessions, rhizome fingers, spice.

INTRODUCTION

Curcuma longa L., commonly known as turmeric, is a tropical perennial monocotyledonous herb belonging to the family Zingiberaceae (Sigrist et al., 2011; Jilani et al., 2012). It is valued for its underground rhizome which contains a yellow coloured phenolic pigment called curcumin which is used as natural colouring agent for food, cosmetics and dye and as an active ingredient in some medicine (Olojede et al., 2009; Karim et al., 2010; Singletary, 2010).Curcumin has a surprisingly wide range of beneficial properties, including anti-inflammatory, antioxidant, chemopreventive and chemotherapeutic activity. Curcumin is a free radical scavenger and hydrogen donor, and exhibits both pro- and antioxidant activity (Hatcher et al., 2008).

Turmeric is a cross-pollinated, triploid species (2n =3x = 63), which can be vegetatively propagated using its underground rhizomes (Sasikumar 2005). Since hybridization is ineffective in most cases, genetic improvement is often limited to germplasm selection and mutation breeding (Ravindran et al., 2007). Evaluation of turmeric cultivars to identify good genotypes suitable for cultivation in different agro-ecologies has been reported. Significant variation in respect to various morphological features and yield components was observed among thirty turmeric germplasm of Bangladesh (Rahman et al., 1992).

Detpiratmongkol et al. (2009) reported that *Phisanulok* cultivar had more plant height, number of leaves, stem and leaf dry weight than *Surat-Thani* cultivar in Thailand. In Tarai region of Uttar Pradesh India, Chaudhary et al. (2006) evaluated five varieties of turmeric viz. *Krishna*, *Suvarna*, *Rajendra Sonia*, *Suguna* and *Sudarshana* and found that the variety *Krishna* recorded highest fresh (405.60 q/ha) and cured rhizome (65.80 q/ha) yield followed by *Rajendra Sonia* and *Suvarna*. Kandiannan, (2015) indicated that fresh rhizome yield per plant varied between 423.7g/plant (Roma) to 792.3g/ plant (NarendraHaldi 1) at Kerela India.

Olojede and Nwokocha (2011) reported that in Nigeria, turmeric can be found growing from low altitude [5m above sea level (asl)] in the Southern coastal plains of the rainforest to the mid-altitude (823m asl) in the Derived Savanna within Longitude 3°02'E - 09°30'E and latitude 4°37'N – 10°04'N. The Derived Savanna covers about 10% of Nigeria's land area and extends southwards from the southern guinea zone into the forest zone (Adegbola and Onayinka, 1976). Inspite of increasing demand for derived products of turmeric in Nigeria which makes its large scale production attractive, it is still cultivated mainly in small plots around homes (Olojede et al., 2005) and in the wild (Olife et al., 2013). To date, no variety has been formally released for cultivation by Nigerian farmers due to lack of information on the suitability of turmeric cultivars for cultivation in different agroecologies of the country. The present effort is an attempt to bridge this information gap; hence, the objective of this trial is to evaluate the performance of different turmeric accessions in NRCRI gene bank with a view to identifying those suitable for production under the derived savanna agro-ecology of Nigeria.

MATERIALS AND METHODS

The experiment was carried out during the rainy seasons of 2012 and 2013 at Igbariam (6.4°N,6.93333°E) in the Derived Savanna of Nigeria. The rainfall pattern is bimodal between April and October, with a mean annual rainfall of 1268.4mm. The dry season falls between November and March. The relative humidity (RH) of the study area is moderately high all the year round with the highest RH of 85% during the wet season and the lowest 64% occurring during the dry season. The temperature range is between 21°C - 35°C. The soil is of the sandy loam textural class and poorly drained; classified as Ultisol (FDALR, 1985); moderately acidic (pH 5.2); with the following chemical properties: Organic Carbon (%) 0.57, Total N (%) 0.07, Available P (mg/g) 5.24 , CaCmol kg-^{1} 2.80, Cmol kg-^{1} 0.80, K. Cmol kg-^{1} 0.12, Na Cmol kg-^{1} 0.36 , Each Acidity Cmol kg-1 1.12, Base Saturation (%) 79 (Obasi, 2012).

The treatment comprised 15 turmeric accessions laid out in randomized complete block design (RCBD) using three replications. The plot size was 9 m^{2} using raised beds and seeding rate of 1rhizome/stand. The plants were spaced 50 cm and 30 cm apart between and within rows, respectively. The beds were mulched soon after planting. Fertilizer was applied at the rate of 400 kg/ha NPK (Nitrogen, Phosphorus and Potassium) 15:15:15 at eight weeks after planting. The experiment was kept weed free by the application of pre-emergence herbicide(Atrazine/metachlor) at the rate of 2.5kg ai per hect are before mulching and later followed by manual weeding. The plants were harvested when leaves had dried. Data were collected on the following growth and harvest parameters: emergence count at 4 weeks after planting (WAP) and 8 WAP, plant height (8, 12, 16 and 20 WAP), number of tillers(8, 12, 16 and 20 WAP), number of leaves (8, 12, 16 and 20 WAP), leaf area (8, 12, 16 and 20 WAP), main pseudo stem girth (stem girth)(8, 12, 16 and 20 WAP), Mother rhizome number (MRN), Primary rhizome number (PRN), and Secondary rhizome numbers (SRN), Mother rhizome weight (MRW), Primary rhizome weight (PRW), Secondary rhizome weight (SRW) and Total rhizome yield. Combined Analysis of variance was carried out on the data using GenStat Discovery Edition Software (VSNi). Significant means were separated using the standard error of the difference of means (SED).

RESULTS AND DISCUSSION

The effect of turmeric accession and year of planting on percentage emergence at 4 and 8WAP is presented in Table 1. The mean plant emergence was generally high ranging from 85 - 100% at 4 WAP as against a range of 93.5 to 100% at 8 WAP. There were significant differences ($P \leq 0.05$) amongst turmeric accessions especially between the least and the highest in this attribute in the two sampling periods. The year effect was not significant. High plant emergence is indicative of adaptability of a genotype to a particular environment.

The stem girth increased with time in all turmeric accessions. The variation of turmeric accessions at each sampling was significant (Figure 1). UT58 and UT60 had the highest and lowest stem girths respectively at most sampling dates. The maximum girth (i.e girth of the main stem at 20WAP) of turmeric accession was bigger in 2013 compared to 2012 (Table 2).

Plant height of some turmeric accessions at different sampling dates is presented in Figure 2. It increased sharply within the first 12 weeks and then gradually up to the 20th week. Height differences became significant at 8WAP and remained at subsequent sampling dates. UT41 was significantly taller than most other accessions at all sampling dates. Maximum plant height (ie Height at 20WAP) ranged from 90.2cm in UT16 to 156.5cm in UT41 but the mean in 2012 and 2013 were similar (Table 2). Jadhav et al. (2009) also found significant differences in height of turmeric accessions with Genotype *Waigaon* recording maximum values 95.91 cm. Detpiratmongkol et al. (2009) reported that *Phisanulok* cultivar had more plant height than *Surat-Thani* cultivar.

Number of leaves per plant increased with sampling date (Figure 3). However this increase was significant only at

Table 1. Percentage Emergence of Turmeric Accessions in 2012 and 2013

	4WAP			8WAP		
Turmeric Accession	**2012**	**2013**	**Mean (Accession)**	**2012**	**2013**	**Mean (Accession)**
UT14	100	100	100	100	100	100
UT16	90	100	95	97	100	98.5
UT25	100	100	100	100	100	100
UT30	100	100	100	100	100	100
UT35	97	100	98.5	97	100	98.5
UT37	100	100	100	100	100	100
UT38	93	100	96.5	100	100	100
UT39	100	100	100	100	100	100
UT41	100	100	100	100	100	100
UT44	97	100	98.5	97	100	98.5
UT46	100	100	100	100	100	100
UT50	97	100	98.5	100	100	100
UT58	100	100	100	100	100	100
UT6	77	93	85	87	100	93.5
UT60	93	100	97	97	100	98.5
Mean (Year)	96.22	99.56		98.22	100.00	

S.E.D (4WAP): Accession(2.81); Year (1.02); Accession x Year (3.97) NS; CV% 3.9
S.E.D (8WAP): Accession(1.92); Year (0.70); Accession x Year (2.71) NS; CV% 3.3

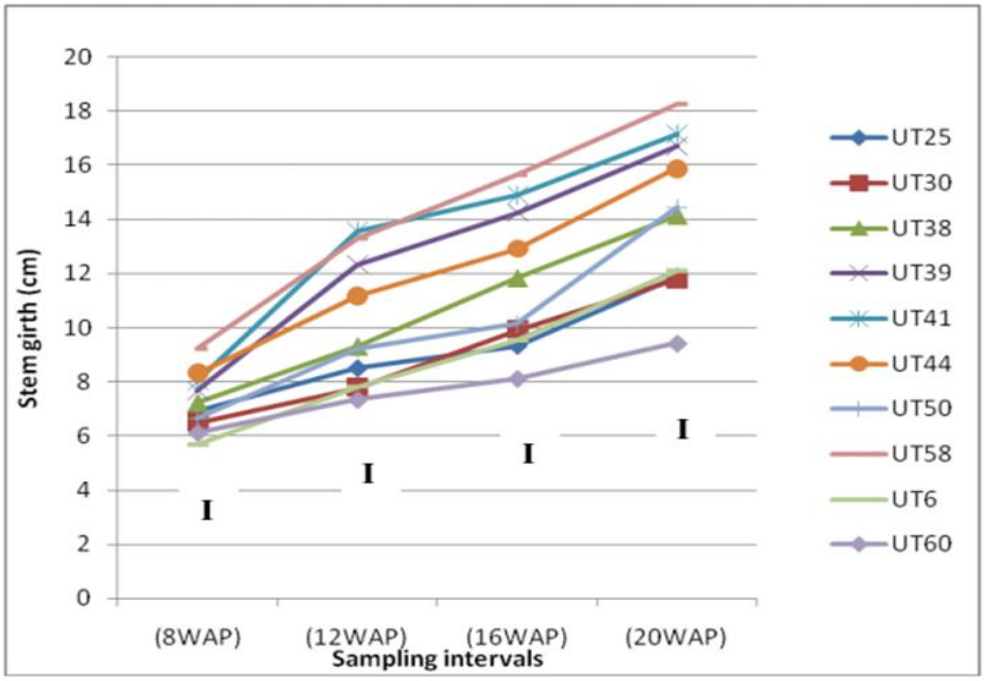

Figure 1: Stem girth of some turmeric accessions at different sampling intervals in two years
SED Stem girth (8WAP): 0.4865; (12WAP): 1.028; (16WAP): 1.031; (20WAP): 1.296

the 16th and 20th WAP. Maximum number of leaves at 20WAP in three cultivars UT41 (10.34), UT44 (10.50) and UT39 (10.67) were significantly lower than that of cultivar UT25 which had the highest number of leaves/plant (11.83) Leafiness of turmeric accessions in 2012 and 2013 were similar (Table 3). Detpiratmongkol et al. (2009) reported that *Phisanulok* cultivar had more leaves than *Surat-Thani* cultivar while Jilani et al. (2012) found that turmeric cultivar *Krishna* had maximum leaves per plant (13.74, 12.97 and 13.73) which was significantly higher than two other cultivars in three localities.

Trend in tillering of turmeric accessions at different sampling dates is presented in Figure 4. Significant differences in number of tillers/plant were observed amongst accessions at different sampling dates. This is in agreement with the report of Detpiratmongkol et al. (2009).

Table 2. Some growth attributes of turmeric accessions at 20 WAP in 2012 and 2013

	Stem Girth (cm)			Leaf Area (cm^2)			Number of Leaves			Number of Tillers			Plant height (cm)		
Accession Number	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**
UT14	9.96	16.68	13.32	613	611	612.00	11.67	11.33	11.50	9.33	7.67	8.50	104.7	103.0	103.85
UT16	9.32	14.6	11.96	588	512	550.00	11.33	11.00	11.16	8.67	7.00	7.84	91.70	88.70	90.20
UT25	11.13	12.65	11.89	721	616	668.50	12.33	11.33	11.83	8.00	7.33	7.67	107.0	94.00	100.5
UT30	9.46	14.13	11.79	690	542	616.00	10.67	12.00	11.34	9.00	8.67	8.84	96.30	107.0	101.65
UT35	8.84	14.22	11.53	560	610	585.00	11.33	10.67	11.00	9.33	7.00	8.16	103.3	98.30	100.8
UT37	9.67	15.38	12.52	551	739	645.00	11.67	10.33	11.00	6.67	6.33	6.50	95.30	109.0	102.15
UT38	10.13	18.15	14.14	511	1030	770.50	11.33	11.00	11.17	9.67	5.67	7.67	93.00	110.3	101.65
UT39	14.25	19.22	16.73	890	1150	1020	11.00	10.33	10.67	5.00	4.67	4.84	104.3	123.7	114.00
UT41	15	19.3	17.15	1322	1207	1264.5	11.67	9.00	10.34	5.00	5.00	5.00	133.3	139.7	136.50
UT44	13.42	18.37	15.89	945	1139	1042.0	11.00	10.00	10.50	6.33	5.33	5.83	107.0	121.7	114.35
UT46	10.58	13.33	11.95	647	570	608.50	11.33	11.67	11.50	7.67	5.00	6.34	103.7	97.30	100.50
UT50	12.25	16.62	14.43	623	651	637.00	12.00	11.33	11.67	8.00	5.67	6.84	103.3	104.0	103.65
UT58	17.03	19.5	18.26	1164	1101	1132.5	11.67	11.33	11.50	7.33	6.00	6.67	120.0	119.3	119.65
UT6	9.96	14.23	12.09	704	522	613.00	11.33	10.67	11.00	9.33	8.33	8.83	97.70	94.00	95.85
UT60	8.92	9.93	9.43	537	611	574.00	11.33	11.00	11.17	7.67	6.33	7.00	96.70	96.00	96.35
Mean	11.33	15.75		738	774		11.44	10.87		7.8	6.4		103.8	107.1	
SED	0.47		1.30	30 (NS)		82	0.18(NS)		0.49	0.25		0.68	2.57 (NS)		7.02
CV%			16.6			18.8			7.7			16.6			11.5

Maximum number of tillers was attained at 20WAP and varied from 4.48 in UT39 to 8.84 in UT30. Mean number of tillers produced was significantly higher in 2012 than in 2013.

Leaf area of turmeric accessions increased with and differed significantly at each sampling dates (Figure 5). Maximum leaf area was attained at 20WAP and varied significantly from 550 cm^2 in UT16 to 1264.5 cm^2 in UT41 (Table 2). The difference between mean leaf area of turmeric cultivars in 2012 and 2013 was not significant although the LA in 2012 tended to be higher. Jilani et al. (2012) and Jadhav et al. (2009) reported significant differences between turmeric cultivars in leaf width and leaf area respectively.

In terms of rhizome yield, the number of Mother rhizome (MRNo) ranged from 23.7 in UT39 to 34.2 in UT35, primary rhizome number(PRNo) ranged from 64.7 in UT39 to 98.4 in UT35 while secondary rhizome Number (SRNo) ranged from 189 in UT41 to 364.4 in UT25. Three accession with the lowest values of MRNo UT39 (23.7), UT41 (24.3) and UT44 (25.2) were significantly lower than UT35 which had the highest number of MRNo/m^2. Most of the accessions did not differ in their number of PRNo/m^2. The only significant difference in this attributes was observed between UT39 and UT35 which were the two accessions with extreme values. UT41 with the lowest number of SRNo/m^2 (189.4) differed significantly in this attribute from five other accessions namely UT14 (325.3), UT25 (364.4), UT35 (294.0), UT46 (299.0) and UT50 (304.8). High number of secondary rhizome produced by the accessions indicates that rhizomes developed fully and that growing conditions were favourable. The mean number of MR produced in 2012 was significantly higher than the number produced in 2013 but the mean number of PR and SR produced in both years did not differ. Olojede et al. (2009) reported that 2 cultivars of turmeric (vars. NCL1 and NCL2) were only significant different on rhizome number in the two years at Umudike while result obtained by Jilani et al. (2012) showed the supremacy of *Krishna* over the other two cultivars in all the three localities, as *Krishna* had maximum finger per plant (31.43, 54.44 & 37.00) in all the three localities.

Weights of MR and SR and total rhizome yield of turmeric varied significantly among accessions (Table 4) ranging from 0.55kg/m^2 in UT60 to 1.45 kg/m^2 inUT41; 0.85 kg/m^2 in UT16 to 1.50 kg/m^2 in UT39; and 2.15 kg/m^2 in UT16 to 4.15 kg/m^2 in UT39. Differences between turmeric accessions in weights of PR were not significant while the year

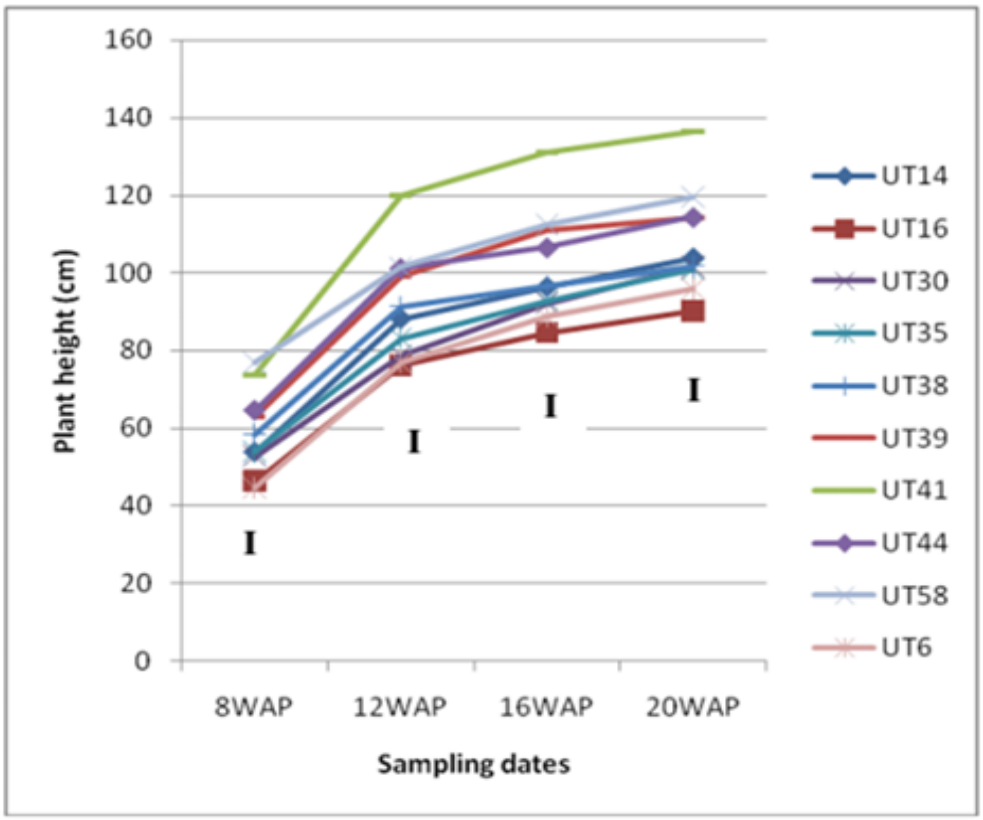

Figure 2: Plant height of some turmeric accessions at different sampling dates in two years
S.E.D:(8WAP): 1.89, (12WAP):2.536, (16WAP):5.72, (20WAP):3.720

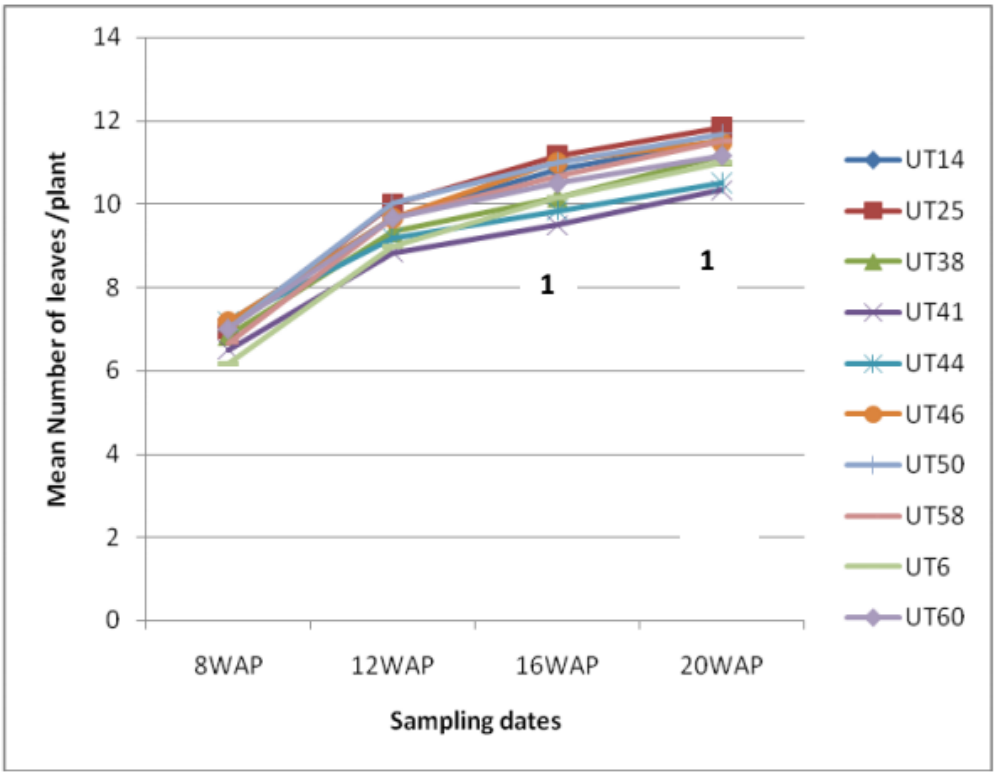

Figure 3: Mean number of leaves of some turmeric at different sampling dates in two years
SED (8WAP): 0.3258 (NS); (12WAP): 0.45 (NS); (16WAP): 0.44; (20WAP): 0.4981 (NS)

Table 3. Rhizome Number/m² of Turmeric Accessions in 2012 and 2013

	Mother Rhizome No.(MRNo)			Primary Rhizome No(PRNo)			Secondary Rhizome No(SRNo)		
Turmeric Accession	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**	**2012**	**2013**	**Mean**
UT14	33.8	26.0	29.9	70.9	81.6	76.2	329.8	320.9	325.3
UT16	28.9	25.6	27.2	71.3	85.1	78.2	273.1	236.2	254.7
UT25	37.6	18.2	27.9	72.2	113.3	92.8	441.6	287.3	364.4
UT30	32.2	23.6	27.9	67.3	65.6	66.4	241.3	270.4	255.9
UT35	39.8	28.7	34.2	106.7	90.2	98.4	328.4	259.6	294.0
UT37	29.8	33.6	31.7	81.3	86.9	84.1	245.8	308.2	277.0
UT38	41.6	18.9	30.2	90.7	60.7	75.7	233.1	176.0	204.6
UT39	25.8	21.6	23.7	65.1	64.2	64.7	228.0	265.6	246.8
UT41	23.6	25.1	24.3	54.2	86.0	70.1	139.8	239.1	189.4
UT44	28.7	21.8	25.2	77.6	83.1	80.3	295.8	220.2	258.0
UT46	31.1	29.6	30.3	78.9	83.8	81.3	278.7	319.3	299.0
UT50	34.7	22.2	28.4	84.4	99.6	92.0	320.7	288.9	304.8
UT58	24.9	27.8	26.3	89.3	70.2	79.8	225.1	176.9	201.0
UT6	35.1	22.2	28.7	82.2	78.4	80.3	252.4	299.8	276.1
UT60	26.4	26.9	26.7	53.1	102.2	77.7	239.8	254.9	247.3
Mean (Year)	**31.6**	**24.8**		**76.4**	**83.4**		**271.6**	**261.6**	

S.E.D (MRF): Accession (3.76) NS , Year (1.37), Accession x Year (5.31); CV% (23.1)
S.E.D (PRF): Accession (13.91), Year (5.08)NS, Accession x Year (19.67) CV% 30.2
S.E.D (SRF): Accession (44.04); Year (16.08) NS; Accession x Year (62.28) NS; CV% 28.6

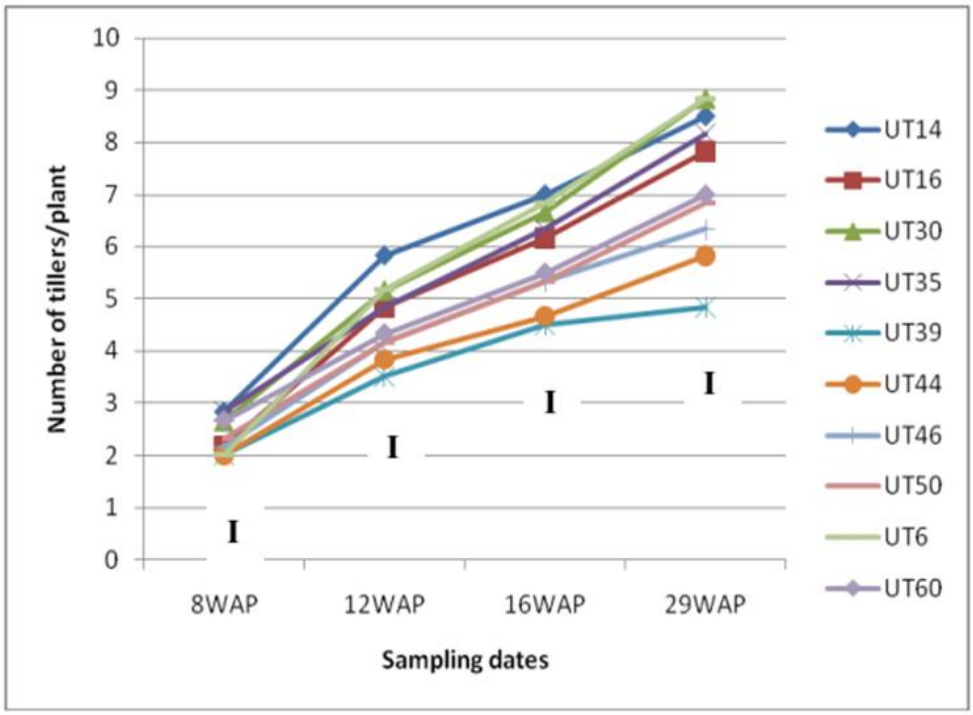

Figure 4: Tillering of some turmeric accessions at different sampling dates in two years

effect was significant with PR yield in 2013 (1.3 kg/m²)being significantly higher than 2012 (0.9 kg/m²), Significant differences between rhizome yields of turmeric accessions have been reported by various authors. Nayak et al. (2006) reported that the rhizome yield per plant varied significantly from 77.66 to 350 g among 17 cultivars. Rahman et al., (1992) recorded highest fresh yield of 44.56 t/ha from T-027 amongst 32 others turmeric accessions evaluated in Bangladesh. Kandiannan, (2015) indicated that fresh rhizome yield per plant varied between 423.7g/plant (Roma) to 792.3g/ plant (NarendraHaldi 1) at Kerela India. On the contrary, Olojede et al. (2009) stated that 2 cultivars of turmeric (vars. NCL1 and NCL2) did not differ in rhizome yield in the two years they were evaluated.

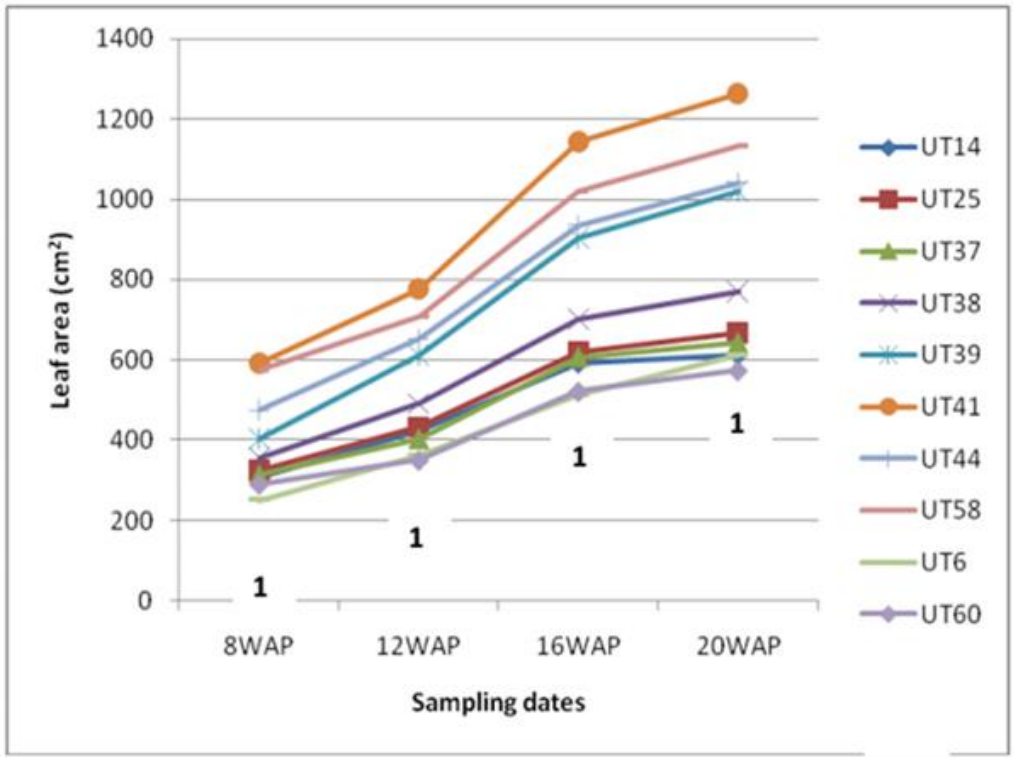

Figure 5: Leaf area of turmeric at different sampling dates in two years
SED: (8WAP): 44.61; (12WAP):54.9; (15WAP): 68.8; (20WAP): 82.0;

Table 4. Rhizome Weight (kg/m²) of Turmeric Accessions in 2012 and 2013

	Mother Rhizome yield			Primary Rhizome yield			Secondary Rhizome yield			Total Rhizome yield (TRY)		
Accession	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
UT14	0.8	0.7	0.75	1.0	1.2	1.10	1.4	1.3	1.35	3.2	3.2	3.2
UT16	0.6	0.4	0.50	0.8	0.8	0.80	1.0	0.7	0.85	2.4	1.9	2.15
UT25	0.7	0.6	0.65	1.2	1.6	1.40	1.5	1.4	1.45	3.4	3.6	3.50
UT30	0.7	0.5	0.60	0.7	0.8	0.75	1.0	1.2	1.15	2.4	2.5	2.45
UT35	0.9	0.5	0.70	0.9	1.1	1.00	1.7	1.2	1.45	3.5	2.8	3.15
UT37	0.7	0.8	0.75	0.8	1.4	1.10	1.0	1.2	1.10	2.5	3.4	2.95
UT38	1.2	1.0	1.10	0.9	1.3	1.10	1.4	1.2	1.30	3.5	3.5	3.50
UT39	1.4	1.3	1.35	1.1	1.5	1.30	1.4	1.6	1.50	3.9	4.4	4.15
UT41	1.3	1.6	1.45	0.8	1.5	1.15	0.8	1.4	1.10	2.9	4.5	3.70
UT44	1.1	1.3	1.20	0.9	1.8	1.35	1.4	1.2	1.30	3.4	4.3	3.85
UT46	0.8	0.8	0.80	1.3	1.4	1.35	1.5	1.4	1.45	3.6	3.6	3.60
UT50	0.8	0.9	0.85	1.0	1.4	1.20	1.0	1.4	1.20	2.8	3.7	3.25
UT58	1.2	1.6	1.40	0.9	1.7	1.30	1.0	1.2	1.15	3.1	4.5	3.80
UT6	0.8	0.6	0.70	0.6	1.0	0.80	1.1	1.3	1.20	2.5	2.9	2.70
UT60	0.8	0.3	0.55	0.7	1.1	0.90	1.1	0.8	0.95	2.6	2.2	2.40
Mean (Year)	0.9	0.9		0.9	1.3		1.2	1.2		3.1	3.4	

S.E.D (MRF): Accession (0.24); Year (0.09) NS; Accession x Year (0.34) NS; CV% 46.5
S.E.D (PRF): Accession (0.27)NS; Year (0.10); Accession x Year (0.38)NS; CV% 42.4
S.E.D (SRF): Accession (0.26); Year (0.09) NS; Accession x Year (0.37) NS; CV% 36.6
S.E.D (TRY): Accession (0.69); Year (0.25) NS; Accession x Year (0.97) NS; CV% 36.7

In general total rhizome yield ranging from 2.15 – 4.15kg/m² produced by turmeric accessions evaluated are acceptable and buttressthe fact that this precious spice is adapted to and can perform well in a derived savanna.

Conflicts of interest

The authors declare no conflicts of interest on this manuscript.

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