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Relationship of Cassava Growth Parameters with Yield, Yield Related Components and Harvest Time in Ibadan, Southwestern Nigeria

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Abstract
The relationship of major growth parameters with yield at various times of harvesting of cassava was investigated during 2007 and 2010 in a tropical Alfisol in Ibadan, Nigeria. Cassava (TMS 30572 and TMS 92/0326) was planted at 1m x 1m (10,000 plants per hectare) and fertilizer (NPK 15-15-15 and organomineral fertilizers) applied at planting using a split-plot arrangement in a randomized complete block design (RCBD) with three replicates. Parameters assessed include plant height, number of leaves, leaf area index (LAI) up to 6 Months After Planting (MAP), fresh and dry root yield, shoot yield, number of roots and harvest index at harvest at 9, 12, 15 and 18 MAP. The LAI at 2-6 MAP in 2007 and 4-6 in 2008 contributed significantly to the root yield while plant height at 1 MAP exhibited a negative relationship with fresh root yield of cassava within the same period ($r=0.47(n=37)p= \leq 0.05$). Root dry yield was positively correlated with fresh root yield ($r=0.46(n=37)$ $p= \leq 0.05$, in 2009) Plant growth parameters at 4-6 MAP all contributed to increased fresh root yield at 12 MAP harvest. Growth parameters at various stages had negative relationship with root yield at 18 MAP harvest. This delay made extra demand for assimilates partitioned in favour of the cassava shoot growth. Cassava should be harvested between 12-15 MAP; 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.
Keywords: Growth parameters, Yield, Correlation coefficient, Months after planting

INTRODUCTION

Cassava is one of the most consumed root crops in the world and second important staple food for energy in sub-Saharan Africa providing up to 285 calories per person/day (Benesi *et al*., 2004).World production in 2012 was estimated at 250 million tonnes with Nigeria as the leading producer, ahead of Brazil with estimated annual production of 54 and 24 million tonnes respectively (UNCTAD, 2012; FAO, 2013). Nigeria's leading role in cassava production is fuelled by research efforts of the International Institute of Tropical Agriculture (IITA) and National Root Crop Research Institute (NRCRI) as well as Federal Government of Nigeria Cassava Transformation Agenda (CTA) in breeding, release and multiplication of improved cultivars to farmers. The crop has a wide adaptability and produces yield in various agroecological and agronomic conditions (Mesut and Ahmet, 2000).

Cassava is grown mainly for its roots and leaves which are consumed in various forms. Recently, ratooning of cassava plants for stems has become a profitable venture for many farmers in Nigeria. Apart from cassava use as food, it is also a major source of feed for animals and raw materials for various industries. Furthermore, cassava products are also popular in international trade, contributing to the economy of exporting countries (Schott *et al*., 2000).

However, the yield and performance of this important crop may be affected by genetic as well as various environmental factors which could be linked to inclement temperatures, water deficit, inefficient distribution of assimilate in favor of the roots and time of harvest (Grant *et al*., 1985; Chang, 1991). The productivity of cassava is also limited by soil nutrient status, increase in yield due to fertilizer application has been severally reported (Obigbesan, 1999; IITA, 2005; Fermont *et al*., 2010; Okpara *et al*., 2010; Edet *et al*., 2013).However, positive yield response to fertilizer application may be due to effects at the level of assimilate source (leaf area and photosynthesis) and at the level of assimilate sinks (number of roots, mass, fruits, etc.) (Marschner, 1989). In Cassava, yield is closely associated with tuber diameter, size and weight (Ntawuruhunga and Dixon, 2010; Agahie, 2011).The shoot and the root compete for photosynthetic assimilates due to cassava's

unique simultaneous development of these two sinks (El-Sharkawy and Cock, 1987), however, to achieve high yield, shoot and root growth must be well balanced. Tewodros and Ayenew, (2012), observed that plant height showed strong and positive correlation with most of the characters including leaf area, fresh root and dry matter yield. Positive contribution of LAI to yield of cassava has been reported (Ekanayake, 1996). Partitioning of assimilates in favor of cassava shoot due to age has also been reported (Githunguri *et al*., 1998). According to Apea-Bah *et al*. (2011), higher accumulation of starch at later stages of growth was due to conversion of glucose making 24 MAP cassava unpalatable and uneconomical time wise. Furthermore, delay in harvest beyond 15 MAP leads to the re-assimilation of reserve food for further development thereby decreasing the regeneration capacity of cuttings.

It is important to understand the relationship between cassava growth parameters and their contribution to yield at various stages of growth of the crop. Knowledge of these agronomic traits assessment and interrelationship at different stages of growth will guide farmers on the appropriate time to harvest both the roots and leaves to get the desired quality. Information on this interrelationship in South Western Nigeria is scarce. Therefore there is a need to study the relationship between cassava growth and yield as well as yield components at various stages of development. Results from this study could guide cassava growers on the best time to apply fertilizer or manure for optimum utilization by the crop. It may also enlighten farmers in areas where cassava leaves are eaten as vegetable on the optimum periods to harvest leaves without significant effects on root yield and quality.

This study was conducted to assess the contribution of various cassava growth parameters to yield and yield related components of cassava at different stages of growth and harvest times

MATERIALS AND METHODS

The experiment was carried out at the University of Ibadan Teaching and Research Farm, AJibode (Lat. $7^0$30'N and Long. $3^0$54'E, Soil type - Alfisol) between 2008 and 2010, to assess the effects of two OF and NPK fertilizer as well as different times of harvesting on cassava yield and yield components of TMS 30572 and TMS 92/0326 cassava varieties. Ajibode is located at about 4.5 kilometers from the International Institute of Tropical Agriculture, (IITA) Ibadan, where the weather information was collected. The site was under cultivation of arable crops for 3 years and fallowed for 3 years prior to clearing on the 28 April, 2008 for first year planting. The soil was disc-ploughed, harrowed and ridged at 1 m apart, soil samples were collected and planting was done manually on the 5th of May, 2008. The experiment was a split-split plot, arranged in a Randomized Complete Block Design (RCBD) with three replicates. Main plot was cassava varieties: TMS 30572 and TMS 92/0326, subplot (11 x 10 m) was 3 fertilizer treatments- No fertilizer (control), OF at 2.5 t/ha and NPK 15-15-15 at 600 kg/ha while sub-subplot (9 x 2 m) treatment was 4 times of harvest (9, 12, 15 and 18 MAP). Cassava cuttings were planted at 1m x 1m spacing, fertilizer was applied at planting while weeding was done at 3, 7 and 12 MAP. The OF used was a commercial type composed of 92% livestock dung mixed with market waste, fortified with 2% SSP and 6 % Urea.

Data on fresh root shoot yield and number of storage roots per plant were taken; 250 g samples of fresh shredded roots were oven-dried at 65^0C to a constant weight to obtain the root dry matter yield, converted to tons/ha. Data were subjected to ANOVA procedure of the generalized linear model of SAS and correlation coefficient analysis. Treatment means were compared using the DMRT at 5% level of probability.

RESULTS

The soil at the experimental site (Table 1) was moderately acidic and of sandy loam textural class. The soils in both years were high in organic carbon and exchangeable K, medium in N content and moderate in P content (FFD, 2012). The critical levels set for optimum yield of cassava were pH 5.2 – 7.0, 0.2% N, 7.3 mg/kg available P and 0.14-1.20 cmol/kg exchangeable K (Howeler, 1991). Analysis of OF indicated considerable nutrient values which may have contributed to soil nutrient availability during the experimental period (Table 1). Total rainfall was higher in 2008 (1393.7 mm) than 1115 mm obtained in 2009 although the rain started earlier in the second year than 2008 (Table 2).

The result of correlation coefficient analyses on the relationship among various cassava growth and yield parameters as affected by the time of harvest in 2008 and 2009 are presented in Tables 4 and 5. The root dry matter, fresh shoot weight and harvest index were positively correlated with fresh root yield of cassava in both years of investigation. Furthermore, in 2009, plant height at 4 and 5 MAP, number of leaves and LAI each at 4 to 6 MAP also had positive relationship with fresh root yield.

The results of the relationship of cassava root yield with various parameters at different harvest times in 2008 and 2009 at Ajibode showed that plant height at 2 to 6 MAP, number of leaves at 1, 3 and 4 MAP, LAI at 3 to 6 MAP and fresh shoot weight were negatively correlated ($r=0.47$, $p = \leq 0.05$) with fresh root yield of cassava at 9 MAP in 2008 while the root dry matter was positively correlated ($r=0.47$, $p = \leq 0.05$) with the same parameter at 9 and 12 MAP in 2009. However, plant height at 5 MAP, LAI at 6 MAP in 2008, number of leaves

at 3 MAP in 2009 were negatively correlated (r=0.46, p = ≤ 0.05) with fresh root yield at 12 MAP.

The fresh shoot weight, LAI at 6 MAP, at 15 months harvest and plant height at 3, 5 and 6 MAP, LAI at 6 MAP, at 18 months harvest in 2008 showed a negative correlation (r=0.46, p = ≤ 0.05) with fresh root yield. Similar trend was observed with plant height and number of leaves at 1 MAP in 2009 when cassava was harvested at 18 MAP. Furthermore, the root dry matter, number of roots and harvest index were positively correlated at 18 MAP in both years of study (Tables 4 and 5).

DISCUSSION

The negative relationship between plant height, number of leaves, LAI, as well as fresh shoot yield, and fresh root yield at the early months of growth, especially when cassava was harvested at 9 MAP could have been as a result of preferential partitioning of more assimilates to the growing shoot at that active growth stage leading to reduction of assimilates translocated to the roots.

Similarly, plant height at 5 MAP, LAI at 6 MAP in 2008 as well as number of leaves produced at 3 MAP in 2009 all had negative relationship with fresh root yield at 12 MAP, indicating that these parameters caused a reduction in fresh root yield of cassava at this period. This was probably due to high demand of assimilates for vegetative growth to the detriment of the root tubers. This means that the root yield of these cassava varieties could still increase if harvest is deferred for a few months. Increase in cassava root yields obtained due to prolonged harvest beyond 12 MAP have been reported (Ngeve, 1985; Nweke *et al*., 1994; Alleman and Dugmore, 2004; Okpara *et al*., 2010).

The shoot yield, LAI at 6 MAP, plant height and leaf production during the early stages of growth caused a reduction in fresh root yield when harvest was delayed till 18 MAP. This was probably as result of the shoot making extra demand of assimilates for growth at this stage. Similar result on partitioning of assimilates in favour of cassava shoot with age of the plant has been reported (Githunguri *et al*., 1998). Higher accumulation of starch/fibre due to conversion of glucose as a result of excessive demand by the shoot system causes reduction in root tuber quality especially when harvest is prolonged for up to 18 months and above (Apea-Bah *et al*. 2010).

CONCLUSION

Based on the result of correlation in this study, growth and yield parameters had profound effects on final root yield at different stages of growth as well as harvest time. Cassava plant development at the early stages of growth (1-3 MAP) make heavy demand on assimilates to the detriment of root bulking. However, beginning from 4 MAP, growth parameters begin to make significant positive contribution to root yield. This period of active growth also coincides with the peak period of leaf area development which is crucial in assimilate manufacture. At this time, harvesting of cassava leaves should be minimized. Furthermore, undue delay of harvest beyond 15 MAP may not result in significant contribution to the final root yield, due to the fact that the crop re-uses the accumulated food in the roots for fresh shoot development with consequent reduction in the root yield and quality. Growth parameters were negatively correlated with root yield of cassava harvested at 9 MAP thereby making this period unsuitable for cassava harvest for optimum yield; however this is dependent on the variety planted.

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Table 1: Soil and fertilizer analysis

Parameters	Soil sample		Organomineral fertilizer
	2008	2009	
pH (H_2O)	5.9	6.0	6.2
Total nitrogen (g/kg)	1.9	2.1	44.2
Organic carbon (g/kg)	22.6	24.9	34.4
Available P (Bray's P1) (mg/kg)	11.5	10.6	11.2
Exchangeable K (cmol/kg)	0.6	0.7	8.4
Textural class	Sandy loam	Sandy loam	N/a

Source of OF: Pacesetter Fertilizer Company, Bodija, Ibadan.

Table 2: Rainfall (mm) data during the experimental period

	Jan	Feb	Mar	Apr	May	June	July	August	Sept	Oct	Nov	Dec
2008	0.0	0.0	99.9	133.1	164.1	208.6	248.9	122.9	292.4	115.8	0.1	7.9
2009	10.1	33.7	24.6	174.9	186.2	181.6	160.0	41.3	154.8	115.9	32.5	0.0
2010	0.0	64.9	50.9	126.2	173.2	212.2	212.1	275.5	294.7	349.9	162.5	0.5

Source : International Institute of Tropical Agriculture **(IITA**) Ibadan

Table 3. Cassava yield and yield related components in 2008 and 2009

	Root production				
Harvesting time	**Fresh root (t/ha)**	**Dry matter (t/ha)**	**Number of roots**	**Fresh shoot(t/ha)**	**Harvest index**
Months after planting		**2008**			
9	14.7	5.4	6.4	13.2	0.52
12	22.9	9.9	6.8	22.7	0.51
15	29.8	16.0	6.5	25.3	0.61
18	32.9	17.7	6.1	24.2	0.57
SE ±	0.64*	0.24*	0.20*	0.65*	0.008*
		2009			
9	21.2	8.1	7.15	14.9	0.57
12	26.6	10.2	7.35	21.1	0.55
15	41.5	17.2	7.64	26.8	0.59
18	33.0	15.3	7.01	28.1	0.54
S E±	0.85*	0.70*	0.25ns	1.00*	0.021ns

SE= Standard error
NS= Not significant
* =Significant at 5% level of probability

Table 4. Relationship of cassava growth parameters with yield, yield related components and harvest time in 2008

Table 4.54. Relationship of cassava growth parameters with yield and time of harvest in 2008

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	#
1	PH 1 MAP																																					
2	PH 2 MAP	.417																																				
3	PH 3 MAP	.276	.747**																																			
4	PH 4 MAP	.021	.426	.748**																																		
5	PH 5 MAP	-.071	.507	.534*	.447																																	
6	PH 6 MAP	.241	.749**	.874**	.734**	.480*																																
7	NL 1 MAP	.040	.699**	.606**	.588*	.507*	.644**																															
8	NL 2 MAP	.050	.508*	.589*	.666**	.642**	.691**	.707**																														
9	NL 3 MAP	.219	.678**	.780**	.554*	.595**	.814**	.528*	.574*																													
10	NL 4 MAP	.135	.755**	.844**	.664**	.532*	.817**	.682**	.603**	.866**																												
11	NL 5 MAP	.237	.620**	.827**	.683**	.575*	.792**	.523*	.660**	.830**	.772**																											
12	NL 6 MAP	.355	.811**	.770**	.692**	.644**	.783**	.621**	.623**	.809**	.783**	.802**																										
13	LAI 2 MAP	-.083	.182	.205	.391	.469*	.368	.404	.821**	.207	.222	.348	.315																									
14	LAI 3 MAP	.199	.710**	.848**	.656**	.622**	.879**	.561*	.704**	.958**	.857**	.867**	.847**	.381																								
15	LAI 4 MAP	.236	.742**	.839**	.747**	.479*	.806**	.625**	.662**	.794**	.932**	.715**	.792**	.324	.850**																							
16	LAI 5 MAP	.181	.705**	.854**	.759**	.627**	.872**	.544*	.734**	.834**	.809**	.893**	.855**	.455	.928**	.859**																						
17	LAI 6 MAP	.274	.804**	.839**	.728**	.734**	.864**	.636**	.731**	.860**	.846**	.778**	.915**	.398	.905**	.869**	.880**																					
18	RDMY 9 MAP	.237	.148	.156	-.095	.142	-.041	-.022	.038	.095	.151	.179	.057	-.038	.121	.198	.120	.063																				
19	SY 9 MAP	.105	.326	.300	.026	.257	.218	.242	.148	.351	.407	.122	.116	-.140	.298	.402	.174	.300	.725**																			
20	FRY 9 MAP	-.015	-.484**	-.644**	-.522*	-.576*	-.639**	-.493*	-.397	-.580*	-.621**	-.385	-.418	-.016	-.549*	-.598**	-.522*	-.653**	-.131	-.625**																		
21	NR 9 MAP	-.215	-.042	-.104	.033	.217	.134	-.103	.076	.131	.172	-.010	-.031	.157	.068	.143	.093	.175	.086	.315	-.394																	
22	HI 9 MAP	-.395	-.209	-.102	-.117	.069	-.290	.022	.005	-.164	-.089	-.199	-.224	-.089	-.128	-.074	-.160	-.221	.510*	.488*	-.059	-.236															
23	RDMY 12 MAP	-.109	.017	.042	-.110	###	.013	.026	.142	.038	.191	-.017	-.141	.074	.097	.229	.023	-.079	.607**	.588*	.024	.004	.646**															
24	SY 12 MAP	.096	.418	.326	.040	.198	.294	.315	.245	.302	.456	.125	.140	-.006	.296	.449	.193	.317	.684**	.937**	-.530*	.293	.467	.723**														
25	FRY 12 MAP	-.068	-.426	-.300	-.213	-.572*	-.371	-.401	-.190	-.318	-.354	-.116	-.285	.000	-.226	-.268	-.192	-.474*	-.028	-.472*	.795**	-.536*	.154	.297	-.399												
26	NR 12 MAP	-.385	-.218	.179	.189	-.109	.114	.058	.161	-.026	-.011	.022	-.172	.149	.077	-.020	-.021	-.042	-.001	.076	-.017	-.228	.371	.368	.164	.250												
27	HI 12 MAP	-.182	-.396	-.265	-.369	-.077	-.273	-.281	-.196	-.209	-.168	-.309	-.517*	-.243	-.308	-.293	-.414	-.339	.300	.471*	-.213	.317	.424	.392	.436	##	.065											
28	RDMY 15 MAP	.082	.130	.082	-.145	-.255	.023	-.081	.048	.094	.225	.058	-.009	.030	.155	.294	.108	-.022	.626**	.471*	.176	-.040	.454	.917**	.617**	.412	##	.133										
29	SY 15 MAP	.219	.439	.402	.102	.175	.366	.292	.248	.356	.507*	.197	.213	.025	.366	.522*	.267	.363	.733**	.909**	-.517*	.287	.376	.711**	.967**	##	.128	.381	.648**									
30	FRY 15 MAP	-.112	-.419	-.357	-.334	###	-.443	-.407	-.286	-.409	-.443	-.088	-.305	.005	-.344	-.453	-.253	-.552*	-.011	-.588*	.862**	-.482*	.071	.094	-.506*	.862**	.167	-.252	.247	-.477*								
31	NR 15 MAP	.228	.154	.445	.442	.576*	.332	.154	.504*	.465	.392	.406	.412	.395	.463	.438	.439	.536*	-.056	.051	-.357	.044	###	-.157	.001	##	.015	.034	-.152	.035	-.293							
32	HI 15 MAP	-.151	-.188	-.232	-.487*	###	-.270	-.309	-.305	-.209	-.063	-.227	-.433	-.279	-.225	-.134	-.280	-.413	.558*	.441	.167	.120	.469*	.783**	.523*	.279	.061	.605**	.726**	.524*	.210	-.445						
33	RDMY 18 MAP	-.005	-.052	-.222	-.356	###	-.308	-.113	-.117	-.192	-.086	-.130	-.167	-.035	-.166	-.097	-.234	-.312	.343	.067	.613*	-.386	.422	.692**	.247	.630**	.255	.008	.780**	.213	.586*	-.267	.555*						
34	SY 18 MAP	.023	.295	.161	-.092	-.037	.084	.133	.102	.152	.324	.034	.079	-.044	.178	.326	.060	.128	.661**	.704**	-.081	.024	.559*	.881**	.844**	.050	##	.290	.862**	.818**	-.096	-.147	.671**	.677**			
35	FRY 18 MAP	-.100	-.340	-.498*	-.403	-.516*	-.501*	-.278	-.291	-.401	-.427	-.300	-.259	-.048	-.382	-.423	-.395	-.526*	-.103	-.465	.882**	-.518*	.200	.222	-.346	.792**	.164	-.269	.350	###	.823**	-.318	.172	.782**	.129		
36	NR 18 MAP	-.108	-.329	-.368	-.259	###	-.423	-.158	-.021	-.408	-.379	-.163	-.205	.231	-.326	-.400	-.322	-.404	-.201	-.627**	.840**	-.565*	.085	.057	-.481	.743**	.178	-.183	.107	-.485	.780**	-.101	.058	.586*	-.045	.792**		
37	HI 18 MAP	.085	-.071	-.265	-.495*	-.279	-.394	-.156	-.148	-.278	-.166	-.244	-.257	-.062	-.263	-.193	-.305	-.386	.209	-.040	.529*	-.477*	.376	.489*	.091	.512*	##	.247	.511*	.077	.456	-.113	.581*	.715**	.419	.548*	.608**	1

* Significant r value at 5%probability (n=) = 0.47

PH = Plant height; NL = Number of leaves; LAI = Leaf area index; RDMY = Root dry matter yield; SY = Shoot yield; FRY = Fresh root yield;
NR = Number of roots; HI = Harvest index
MAP = Months after planting

Table 5. Relationship of cassava growth parameters with yield, yield related components and harvest time in 2009

Table 4.55. Relationship of cassava growth parameters with yield and time of harvest in 2009

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	PH1MAP																																					
2	PH2 MAP	.732**																																				
3	PH3 MAP	.747**	.919**																																			
4	PH4 MAP	.650**	.848**	.925**																																		
5	PH5MAP	.722**	.837**	.847**	.877**																																	
6	PH6 MAP	.642**	.789**	.792**	.879**	.946**																																
7	NL 1MAP	.701*	.527*	.549*	.543*	.647**	.584*																															
8	NL 2 MAP	.745**	.700**	.653**	.573*	.659**	.539*	.351																														
9	NL 3 MAP	.719**	.552*	.596**	.558*	.648**	.498*	.608**	.575*																													
10	NL 4 MAP	.604**	.567*	.700**	.767**	.780**	.714**	.541*	.509*	.728**																												
11	NL 5 MAP	.633**	.743**	.741**	.792**	.808**	.740**	.614**	.649**	.728**	.862**																											
12	NL 6 MAP	.642**	.697**	.756**	.718**	.692**	.592**	.550*	.758**	.656**	.744**	.805**																										
13	LAI 2 MAP	.713**	.829**	.813**	.829**	.842**	.786**	.491	.866**	.587*	.686**	.768**	.818**																									
14	LAI 3 MAP	.537*	.440	.513*	.487*	.628**	.561*	.275	.541*	.640**	.657**	.434	.541*	.659**																								
15	LAI 4 MAP	.608**	.678**	.815**	.866**	.840**	.806**	.467*	.578*	.601*	.904**	.754**	.746**	.829**	.763**																							
16	LAI 5 MAP	.609**	.740**	.741**	.748**	.845**	.768**	.509*	.737**	.650**	.681**	.738**	.791**	.883**	.769**	.794**																						
17	LAI 6 MAP	.504*	.626**	.695**	.657**	.672**	.617**	.340	.712**	.508*	.526*	.504*	.768**	.823**	.756**	.714**	.874**																					
18	RDMY 9 MAP	-.356	-.016	.058	.123	-.205	-.178	-.195	-.386	-.278	-.061	-.164	-.099	-.160	-.246	.039	-.211	-.095																				
19	SY 9 MAP	-.224	-.027	.055	.202	-.020	-.062	.049	-.241	.030	.250	.129	.154	.034	-.056	.264	-.019	-.049	.771**																			
20	FRY 9 MAP	-.440	.005	.008	.067	-.138	-.046	-.466	-.373	-.442	-.298	-.346	-.408	-.178	-.129	-.076	-.110	-.024	.676**	.229																		
21	NR 9 MAP	.226	.270	.320	.167	.073	.076	-.100	.125	-.138	.018	-.111	-.014	.130	.242	.172	.107	.193	.125	-.298	.384																	
22	HI 9 MAP	-.010	-.038	.040	.027	-.183	-.240	.094	-.078	-.133	.098	-.001	.155	-.081	-.330	.032	-.326	-.217	.606**	.619**	-.077	-.007															
23	RDMY 12 MAP	-.306	-.071	.029	.096	-.222	-.195	-.035	-.351	-.202	-.117	-.170	-.054	-.166	-.287	-.023	-.183	-.036	.925**	.733**	.551*	-.058	.578*														
24	SY 12 MAP	-.164	-.032	.062	.151	-.073	-.120	.168	-.248	.085	.112	.060	.179	-.041	-.186	.116	-.077	-.046	.721*	.909**	.120	-.432	.637**	.799**													
25	FRY 12 MAP	-.424	.032	.037	.047	-.163	-.051	-.461	-.343	-.496*	-.334	-.321	-.396	-.188	-.204	-.110	-.133	-.043	.620**	.117	.963**	.417	-.092	.516*	.033												
26	NR 12 MAP	-.125	.293	.152	.156	-.025	.079	-.257	.125	-.418	-.345	-.079	.005	.155	-.306	-.173	.058	.171	.210	-.202	.482*	.340	-.086	.131	-.178	.535*										
27	HI 12 MAP	-.223	-.312	-.203	-.157	-.351	-.377	.021	-.369	-.222	-.087	-.247	-.216	-.306	-.390	-.130	-.508*	-.376	.676**	.671**	.116	-.145	.836**	.711**	.685**	.075	-.243										
28	RDMY 15 MAP	-.386	-.107	-.019	.039	-.257	-.239	-.102	-.399	-.225	-.125	-.183	-.067	-.216	-.291	-.046	-.200	-.073	.940**	.767**	.557*	-.091	.574*	.987**	.818**	.522*	.108	.688**									
29	SY 15 MAP	-.159	-.142	-.018	.058	-.138	-.205	.188	-.311	.107	.115	-.007	.111	-.141	-.175	.071	-.167	-.120	.690**	.886**	.052	-.410	.682**	.777**	.975**	-.046	-.328	.768**	.791**								
30	FRY 15 MAP	-.414	-.027	-.023	-.037	-.246	-.134	-.502*	-.335	-.557*	-.412	-.387	-.437	-.245	-.260	-.200	-.187	-.096	.555*	.012	.926**	.487*	-.104	.455	-.060	.981**	.578*	.035	.457	-.130							
31	NR 15MAP	.267	.562*	.541*	.539*	.281	.210	.274	.369	.439	.404	.540**	.568*	.531*	.200	.425	.414	.433	.427	.436	.105	.167	.317	.394	.395	.086	.246	.166	.371	.324	.018						
32	HI 15 MAP	-.456	-.481*	-.408	-.351	-.581*	-.589*	-.206	-.491*	-.374	-.312	-.438	-.290	-.457	-.488*	-.323	.593*	-.445	.709**	.702**	.170	-.214	.784**	.748**	.749**	.112	-.147	.902**	.758**	.799**	.092	.122					
33	RDMY 18 MAP	-.569*	-.144	-.089	-.076	-.336	-.226	-.570*	-.436	-.550*	-.330	-.398	-.334	-.293	-.223	-.141	-.235	-.050	.754**	.308	.890**	.287	.107	.661*	.234	.918**	.432	.240	.692**	.174	.893**	.101	.334				
34	SY 18 MAP	-.325	-.134	-.008	.084	-.136	-.139	-.007	-.385	-.079	.022	-.126	.002	-.114	-.115	.110	-.124	-.013	.812**	.887**	.360	-.319	.527*	.856**	.928**	.270	-.130	.695**	.879**	.906**	.164	.289	.747**	.471*			
35	FRY 18 MAP	-.474*	-.092	-.071	-.094	-.316	-.207	-.570*	-.365	-.566*	-.440	-.423	-.447	-.300	-.292	-.249	-.242	-.105	.563*	.015	.910**	.430	-.092	.471*	-.037	.970**	.573*	.057	.479*	-.102	.988**	.012	.124	.923**	.194		
36	NR 18 MAP	-.574*	-.387	-.345	-.392	-.471*	-.460	.820**	-.261	-.378	-.318	-.530*	-.405	-.325	.067	-.198	-.313	-.071	.314	.034	.521*	.318	-.012	.158	-.113	.486*	.066	.100	.214	-.086	.477*	-.040	.241	.596**	.124	.530*	
37	HI 18 MAP	-.571*	-.414	-.395	-.397	-.549*	-.424	-.654**	-.571*	-.751**	-.480*	-.545*	-.632**	-.620**	-.493*	-.465*	-.575*	-.516*	.367	-.104	.626**	.429	.042	.204	-.221	.690**	.373	.104	.236	-.208	.770**	-.319	.180	.699**	-.054	.783**	.477*	1

* Significant r value at 5%probability (n=) = 0.47

PH = Plant height; NL = Number of leaves; LAI = Leaf area index; RDMY = Root dry matter yield; SY = Shoot yield; FRY = Fresh root yield;
NR = Number of roots; HI = Harvest index
MAP = Months after planting

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