Effect of moisture stress on leaf and root production in cassava (*Manihot esculenta* Crantz.)

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Abstract

Field experiments were conducted at the Agronomy farm of College of Horticulture, Vellanikkara during 2015-16 to assess the effect of moisture stress on leaf production and root yield of cassava varieties grown in different seasons. Four varieties (Vellayani Hraswa, Sree Vijaya, M4 and Sree Athulya) of varying duration were planted in three seasons *viz*., May, October and December. The results revealed that the highest leaf production, root weight and chlorophyll content were recorded for the crops planted in May and the lowest in December planted crop. Among the varieties, Sree Athulya, the long duration variety, produced significantly higher number of leaves when planted in October and December, whereas the short duration variety, Sree Vijaya, produced higher number of leaves compared to Vellayani Hraswa for both the planting seasons. Root fresh weight was highest for May planting followed by October and December planting. Among the varieties, Sree Athulya and Sree Vijaya recorded higher leaf retention and were observed to be more drought tolerant when moisture stress occurred during early stages of growth.

Key words: Cassava varieties, Chlorophyll, Leaf area index, Leaf scars, Root fresh weight.

Introduction

Cassava (*Manihot esculenta* Crantz.) is a tropical plant with its distribution almost confined to the tropical zones. It is however not very fastidious or exacting in its climatic requirement. Though a very warm and humid climate is preferred by cassava, when cultivated in the tropics, it is subjected to highly varying temperature, precipitation, photoperiod and solar radiation (Alves, 2002).

Cassava as a crop is regarded to be tolerant to sporadic and seasonally extended drought episodes. However, prolonged dry period and extreme environmental fluctuations impose significant yield loss in the crop (Howeler, 1991). Several reports have suggested that the critical period for water deficit in cassava is from the first to the fifth month after planting, i.e., the stage of rapid leaf growth, root initiation and tuberization (Agili and Pardales, 1997; Alves, 2002).

The leaves of cassava plant are borne on long slender petioles, with the first leaves appearing about 10 days after planting (DAP). The leaf takes 15 to 20 days to enlarge completely and remains active for a variable length of time. The photosynthetic process contributes positively to plant growth by 30 DAP, when true leaves begins to expand (Cock et al., 1979). The rate of leaf production and longevity of leaves are the major determinants of leaf area index (LAI), which is associated with yield. Fibrous roots start emerging 15 DAP, replacing the first adventitious roots. Of these, nearly three to 14 fibrous roots become storage roots, which can be distinguished 60 to 90 DAP; they continue to bulk up to harvest.

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According to El-Sharkawy et al. (1992), the most active vegetative growth for cassava occurs between 90 and 180 DAP. Taking into account the phenology of the crop, the present paper attempts to assess the effect of moisture stress on leaf production and its influence on the root fresh weight of crop in four varieties of cassava raised in three different seasons with varying rainfall availability.

Materials and Methods

The field experiment was conducted in the Agronomy farm of College of Horticulture Vellanikkara (10° 31' N latitude and 76° 13'E longitude) in Thrissur District of Kerala. Treatments included four cassava varieties of different duration *viz.,* Vellayani Hraswa, Sree Vijaya (each of 6 months duration), M4 and Sree Athulya (each of 10 months duration), planted in three seasons *viz.,* May, October and December of 2015-16. The seasons were selected based on the rainfall distribution pattern in Kerala. The experiment was laid out in a randomized block design with four replications, the net plot size being 5.4 m x 5.4 m. Monthly precipitation data was recorded during the period of study. Cassava crops were raised as per the package of practice recommendations of Kerala Agricultural University (KAU, 2011). Observations on plants were recorded at 2, 4 and 6 months after planting (MAP) for short duration varieties, and also at 8 and 10 MAP for the long duration varieties. Leaf area index was calculated as suggested by Hunt (1982). Chlorophyll content in leaf was estimated using the formula suggested by Yoshida (1972). Statistical analysis was done using WASP tool. For long duration varieties, at 8 and 10 MAP, the mean values were compared using t-test.

Results and Discussion

Precipitation during cropping seasons

Data on the mean bi-monthly rainfall received by the crops planted during different seasons are presented in Table 1. The cassava crop was grown purely under rainfed condition. The first crop was planted at the start of rainy season (i.e., end of May), and it received a total rainfall of 2317 mm for the first six months and 133.37 mm rainfall during the remaining four months. This ensured adequate moisture almost throughout the cropping period. The second crop planted in October received comparatively less initial rainfall (310 mm) during the first six months, and 1500 mm in the next four months. Thus, a higher amount of rainfall was received in the later stages of development of the crop. Mean monthly rainfall for the initial three months was only 45 mm for the December planted crop and 1538.40 mm for the remaining months. The third crop was hence subjected to a severe limitation of moisture in the beginning of its growth. Moisture stress during any time of the initial six months period of crop growth could reduce tuber yields (Alves, 2002). According to Burns et al. (2010), the response of cassava to drought depends upon the duration and severity of water stress and the stage of development of the cultivar.

Cassava leaf production

Leaf retention, as measured by the number of scars, was recorded during all growth stages of the four cassava varieties. The data on the number of leaves recorded at two months interval are presented in Table 2. Significant differences in number of leaves per plant among the varieties were observed during the crop growth. Vellayani Hraswa and Sree Vijaya recorded higher number of leaves during the early

Table 1. Rainfall receipt during crop duration of cassava planted in different seasons

Planting season	Bi-monthly rainfall (mm)					Total rainfall (mm)
	First 2 months	Second 2 months	Third 2 months	Fourth 2 months	Fifth 2 months	
May	1139.9	563.0	355.0	112.1	21.2	2191.20
October	239.5	35.2	35.6	925.4	573.9	1809.60
December	35.2	35.6	925.4	573.9	123.3	1693.40

Table 2. Number of leaves per plant in different cassava varieties planted in three different seasons

Treatments	No. of leaves /plant														
	May planting					October planting					December planting				
	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP
Vellayani Hraswa	63	242	90	-	-	64	96	46	-	-	27	14	38	-	-
Sree Vijaya	59	336	44	-	-	68	99	105	-	-	20	21	51	-	-
TM_4	46	250	323	340**	351**	58	86	153	123**	110**	24	26	52	67**	59**
Sree Athulya	36	125	247	267**	290**	60	104	175	168**	150**	15	33	64	136**	23**
CD (0.05)	8.25	15.97	6.10	S	S	5.13	4.80	27.83	S	S	5.13	4.80	27.83	S	S

** represent that the values are significant at P (T<=t) two tail

Table 3. Number of leaf scars per plant in different cassava varieties planted in three different seasons

Treatments	No. of leaf scars/plant														
	May planting					October planting					December planting				
	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP
Vellayani Hraswa	0.25	61	134	-	-	0.750	34	129	-	-	0.250	24	40	-	-
Sree Vijaya	0.00	45	98	-	-	0.250	25	114	-	-	0.00	17	25	-	-
M_4	0.00	43	95	358**	386**	0.250	22	96	137**	147.**	0.00	25	43	96**	189.**
Sree Athulya	0.00	23	75	242**	287**	0.00	19	79	105**	94**	0.00	28	36	80**	170**
CD (0.05)	NS	5.97	9.53	S	S	NS	0.923	8.59	S	S	NS	3.62	9.71	S	S

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development stages in all the three seasons whereas the long duration varieties, M4 and Sree Athulya recorded significantly higher number of leaves towards the later stages of their growth. Number of leaves was significantly lower for December planting season compared to the other planting seasons. This could be related to the lower rainfall experienced as compared to May planted crop. Sprouting of leaves commenced soon after the receipt of rainfall, but a sudden dip in rate of leaf number production was recorded between 2 and 4 MAP for all December planted cassava varieties except Sree Athulya. Later, an increase was noted between 4 and 6 MAP consequent to receipt of rains. Alves and Setter (2000) documented that leaves of plants under stressed condition have the capacity to regain growth soon after re-watering.

Perusal of the data on the number of leaf scars (Table 3) revealed significantly higher number for May planting at 4 MAP, followed by October planting. The short duration variety Vellayani Hraswa recorded more number of leaf scars among the short duration varieties, while M4 showed less leaf retention among the long duration varieties. Sree Athulya recorded less number of leaf scars during all the growth stages irrespective of the season of planting, indicating better retention.

In Vellayani Hraswa, both leaf production and leaf retention were less compared to other varieties, while Sree Vijaya, also of short duration, retained a higher number of leaves indicating higher moisture stress tolerance ability. Based on the studies in chick pea, Parameshwarappa and Salimath (2008) reported that the effect of intensity and duration of stress is dependent on the plant species and its stage of growth. The variety Sree Athulya was found to retain more leaves and less number of scars under varying rainfall availability in different seasons of planting. El-Sharkawy et al. (1992) reported that high retention or staygreen traits are positively correlated with drought tolerance. Hence the better leaf retention character exhibited by Sree Athulya can be interpreted as its ability to withstand moisture stress.

Leaf Area Index

Significant variations in LAI were recorded with the planting seasons (Table 4). In the present study it was found that the LAI was lowest during initial period of growth (2MAP), increased as growth progressed and finally declined towards the harvest stage. It followed the pattern of a slow increase during the first two months of growth period, followed by a rapid increase and decline thereafter as elucidated by Cock (1976). Leaf area index was

Table 4. Leaf area index of different cassava varieties planted in three different seasons

Treatments	LAI														
	May					October					December				
	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP
Vellayani Hraswa	0.52	3.41	2.56	-	-	0.42	3.20	2.06	-	-	0.320	2.50	2.00	-	-
Sree Vijaya	0.72	2.98	2.60	-	-	0.63	3.02	2.84	-	-	0.540	2.71	1.80	-	-
M_4	0.88	2.78	3.01	2.98**	1.26**	0.56	2.23	2.99	2.60**	1.07**	0.750	2.01	2.37	1.97**	1.54**
Sree Athulya	1.00	2.60	3.12	3.00**	1.44**	0.96	2.56	3.00	2.91**	1.27**	0.890	2.41	2.50	2.10**	1.70**
CD (0.05)	NS	0.019	0.015	S	S	NS	0.029	0.044	S	S	NS	0.014	0.012	S	S

** represent that the values are significant at P (T<=t) two tail

found to be highest at 4 MAP for the short duration varieties and at 6 MAP for the long duration varieties. The LAI recorded in Vellayani Hraswa for May and October planting seasons were highest (3.41 and 3.20 respectively) while Sree Vijaya recorded higher LAI (2.71) for December planting. Significantly higher LAI was observed for Sree Athulya at 6 MAP for all the planting seasons. The highest LAI recorded fell in line with the optimum LAI of 3 to 3.5 reported in cassava for storage root bulking rate (Cock, 1979).

Considering the three planting seasons, LAI for the crop was highest for May planted and was lowest for December planted cassava varieties. This indicated the susceptibility of varieties to moisture stress. The overall reduction in LAI in the December planted crop was 34.4 per cent for Vellayani Hraswa and 24 per cent for Sree Athulya respectively, when compared to May planting. Leaf number and LAI in cassava has been positively related to the amount of rainfall (Lenis et al., 2006).

Chlorophyll content

Photosynthetic pigment content is an important indicator for plants under drought stress. The variations in chlorophyll content in the different varieties in response to the rainfall in the different planting seasons are depicted in Fig.1. Among the varieties, Sree Athulya recorded significantly higher Chl a and b contents compared to the other varieties at all stages of growth for the May planted crop. In the October planted crop, Chl a and b contents (1.29 and 0.98 mg/g) respectively were significantly higher in Sree Vijaya at 4 MAP, and Chl a values were on par with that of M4. The long duration variety Sree Athulya recorded significantly higher Chl a content (1.76 mg/g) and Vellayani Hraswa recorded significantly higher Chl b content (0.64 mg/g) at 6 MAP. In the December planted crop, Sree Athulya was observed to have significantly higher Chl a content (0.27 mg/g) at 2 MAP, and Sree Vijaya (1.38 mg/g) was at par with Sree Athulya (1.24 mg/g) at 4 MAP, while at 6 MAP M4 (1.57 mg/g) was at par with Sree Athulya (1.48 mg/g). Chl b content was significantly higher for Vellayani Hraswa (0.57mg/g) at 4 MAP, but during the later stages, Sree Athulya recorded significantly higher content.

Among the planting seasons, significantly lower Chl a and b contents were recorded for the crops planted in December, compared to those planted in May and October. This can attributed to the

Table 5. Root fresh weight of different cassava varieties planted in three different seasons

Treatments	Root fresh weight (g /plant)														
	May					October					December				
	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP	2MAP	4MAP	6MAP	8MAP	10MAP
Vellayani Hraswa	459	1218	1420	-	-	82	298	1201	-	-	55	183	651	-	-
Sree Vijaya	386	1323	1750	-	-	178	695	1384	-	-	50	145	840	-	-
M_4	534	1468	2350	2780**	2900**	87	533	989	1017**	1103**	114	335	497	738**	1000**
Sree Athulya	788	2271	2799	2988**	3210**	81	369	997	1183**	1299**	124	320	387	934**	1250**
CD (0.05)	NS	376	473	S	S	14	126	297	S	S	19	67	167	S	S

** represent that the values are significant at P (T<=t) two tail

differences in rainfall availability and the moisture stress experienced by the crops planted in the different seasons. As noted earlier, December planted crops were subjected to maximum moisture stress. Sayedh (2003) documented that drought stress inhibits Chl a/b binding proteins which would lead to reduction of the light harvesting pigment protein associated with photosystem II. Farooq et al. (2009) reported that chlorophyll a and b contents varied under drought stress.

Root fresh weight

Root fresh weight per plant was recorded by destructive sampling at bimonthly intervals of plant growth (Table 4). Significantly higher root fresh weights were recorded for Sree Athulya during all the stages for the May planted crop. M4 variety recorded a comparable value with Sree Vijaya at 6 MAP. In October planted varieties, Sree Vijaya recorded significantly higher root fresh weight during its growth (at 2, 4 and 6 MAP), and Sree Athulya was found to be superior to M4 among the long duration varieties. In the December planted crop also, a similar response of varieties was noticed.

Root yield of cassava was affected by the period of moisture stress experienced. The May planted crop, which received adequate moisture throughout its growth, produced highest root fresh weight per plant for all the varieties. The October planted crop received less rainfall in the initial stages, but sufficient rainfall in the later stages of growth with root yield being consequently less than May planted crops. The December planted crops experienced severe water stress in the initial month of growth, the rainfall received being just 45 mm. This was reflected in the low root production at 4 and 6 MAP. The receipt of rains from the fifth month had a marked impact on the long duration varieties, as revealed by the increase in the number of leaves per plant and a consequent improvement in storage root production. The storage roots are the major sink of photo assimilates during the later stages of growth. According to Aresta and Fukai (1984), cassava storage root development is sensitive to drought and photosynthesis and moisture stress during initial stages severely affected storage root yield during later stages. Even though long duration variety Sree Athulya was found to have better root yield per plant under low rainfall condition, short duration variety Sree Vijaya was observed to perform well when planted in October. This may be due to the ability of these varieties to retain leaves under varying rainfall availability (Table 2). This is in accordance with the observations of Setter and Fregene (2007). The study by Kanapathy (1974) revealed that tuber weight is positively correlated to the number of leaves and only the cultivars that had the capacity to retain a large number of leaves were high yielders. The superior storage root yield in Sree Athulya and Sree Vijaya may be due to higher number of leaves retained on plants towards the end of the drought period and new leaves produced during the recovery phase than in the other varieties.

Varietal characters or genotype have a great influence on the effect of moisture stress on the growth and yield of cassava (Farooq et al., 2009). Planting of cassava in the traditional period, i.e., in May, resulted in highest leaf production and storage root formation. Among the cassava varieties Sree Athulya and Sree Vijaya were concluded to be more drought tolerant than M4 and Vellayani Hraswa and thus are more suitable when dry spells and moisture stress were expected during the initial stages of crop growth.

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