Int.J.Curr.Microbiol.App.Sci (2018) *7*(7): 1455-1469

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 07 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.707.173

Leaf Morphological and Physiological Traits and their Significance in Yield Improvement of Fifteen Cashew Varieties in West Coast Region of Karnataka, India

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Keywords

Cashew (*Anacardium occidentale),* Specific Leaf Weight (SLW), Specific Leaf Area (SLA), Leaf chlorophyll contents, Yield components and morphological and physiological traits

Article Info

Accepted:
10 June 2018
Available Online:
10 July 2018

A B S T R A C T

Understanding complex factors controlling yield is very crucial to the improvement of plant performance. Cashew (*Anacardium occidentale L.*) is an important nut crop of social and economic importance for India. The low productivity of raw cashew nut is the major constraint. As detailed morpho- physiological characterization is one of the key steps for yield improvement, this study was carried out to analyze genotypic variation in yield and yield components of fifteen cashew accessions. Here, we relate leaf morphological traits of fifteen cashew varieties to their nut yield and other yield components. Significant differences in leaf morphological and physiological traits observed among cashew accessions. The specific leaf weight was maximum in Vengurlla-3 and Vengurlla -4. The content of chlorophyll a and total chlorophyll was highest in Bhaskara whereas Selection-2 had highest total carotenoid content. The total number of hermaphrodite flowers, sex ratio and total number of flowering panicle was highest in Kanaka, Selection-2, Ullal-2, Ullal-3 and Vengurlla-4 respectively. The nut and kernel weight were highest in Priyanka whereas nut yield and shelling percentage were maximum in Ullal-1, Bhaskara and Ullal-2. Associations between yield traits and leaf morphological traits showed that leaf area (LA), specific leaf area (SLA) and specific leaf weight (SLW) can be regarded as primary yield attributing traits to improve nut yield through increase in nut number per tree, nut weight and panicle number per tree. Therefore, we conclude that leaf morphological and physiological traits are important not only for species identification but also for genetic divergence to improve plant performance influencing yield.

Introduction

The effective display of leaves in a canopy is crucial for plant functioning because it determines the efficiency of the photosynthetic conversion of available light to assimilate and thus influences the potential growth of plants. The carbon assimilates necessary for yield improvement is produced via photosynthesis. Thus, total biomass accumulation depends on rate of biomass production and growth duration (Peng *et al.*, 1991). In any crop system, biomass production is associated with physiological processes such as leaf area production, leaf area retention and net photosynthetic rate. Plant traits are fundamental for adaptation to different environments and are related to important physiological processes such as carbon gain and photosynthesis (Takayoshi *et al.*, 2001). The most widely accepted variables among leaf traits are the specific leaf weight (SLW) which is the ratio between leaf dry mass and leaf area and its inverse specific leaf area (SLA) which has been frequently used as an indicator of differential functional strategies in plant species (Coley *et al.*, 1988). The leaf traits SLW and SLA have been proven to be correlated with leaf processes such as photosynthetic rate (Oren R, *et al.*, 1986), relative growth rate and resource use (Garnier, 1994). SLW and SLA are one of the major variables responsible for resource capture, usage and availability (Grime *et al.*,1997).

To understand the functional consequences of variation in plant traits under varying environments, insights into pigment systems and light interception play significant role. Chlorophylls are the main pigments involved in light capture for important physiological processes viz., photosynthesis and other photochemical reactions. Hence, the amount of light captured by leaf is related to leaf chlorophyll content and therefore leaf chlorophyll content may be used as an indicator of the light environment during plant growth. Leaf chlorophyll content could be used to assess leaf nitrogen content in crops (Gaborcik, 2003), SLA in peanut (Nageswara *et al.*, 2001) and transpiration efficiency in wheat (Fotovat *et al.*, 2007). Campbell *et al.*,(1990) suggested that differences in leaf thickness may cause variation in the leaf chlorophyll and leaf nitrogen content relationship. A positive relationship was observed between leaf chlorophyll content with SLA in wheat (Araus *et al.*, 1997) although negative correlation was reported for barley (Bort *et al.*, 1998). Thus, the relationships between leaf thickness, leaf density, SLA, SLW and LWC with leaf chlorophyll content act as important indicator for plant strategies influencing yield.

Cashew (*Anacardium occidentale L*.) is an important tropical tree crop grown for its edible kernel being highly nutritive and low cholesterol content, apple and industrially important cashew nut shell liquid (CNSL). Cashew, a high export oriented crop, is main source of cash income for millions of small hold farmers worldwide. Today, cashew is produced in about 32 countries with total world production of 2.7 million tons. World's total area under cashew cultivation is around 35100km^2 with India ranking first in land utilization (730000 ha) for its production. Despite the importance of cashew as commodity crop with increasing cultivation worldwide, the world average yield of cashew raw nuts is still as low as 780 kg/ha (FAO, 2008).

Several factors have been described to be closely related to yield potential of cashew trees ranging from availability of poor planting materials (Chacko *et al.*, 1990); plant architecture to floral biology and its interaction with environment (Parameswaran *et al.*, 1984). Production of low percentage of hermaphrodite flowers, poor fruit set, immature fruit drop and low fruit retention are other major limiting factors for low yield in cashew which need due attention (Patnaik *et al.*, 1985). Available literatures showed that little is known about various complex factors controlling yield in cashew (Chacko *et al.*, 1990) and in particular the extent to which morphological and physiological factors influencing yield. Little is known about reproductive factors such as pollination, fertilization and fruit development controlling yield that are required for developing long term breeding strategies in cashew. To increase the productivity of raw nuts and improve the quality of nuts, there is need to select desirable genotypes from germplasm of wide genetic diversity (Chacko *et al.,* 1990) and use superior materials in breeding programs. Breeding of cashew is mostly based on selection of desirable agronomic traits such as nut size, nut weight, tree spread, colour of apple, size of fruit, length of panicle and overall yield (Mneney *et al.,* 2001). Knowledge of the association between traits such as yield and other traits in the population is desirable in breeding cultivars which have higher yield contributing factors. Traits associated with yield may be used either as indirect selection criteria or as a selection index for higher yield.

It is surprising to note that cashew considered at large as a hardy species, descended for centuries to the present status of international importance with least knowledge about its physiological abilities to flourish even under uncared conditions of India. Until recent times, cashew was considered as a waste land crop and was not given crop management attention. There has been a long delay with big research gap in understanding the physiology of cashew and its association in yield gain. Some studies has been conducted on comparative physiology of sun and shade leaves and fruiting and abscission pattern in cashew (Subbaiah, 1983) and subsequently little information is available on interaction of morphological traits with nut yield. Yet, the detailed work on identifying and correlating the physiological traits with plant growth rates under controlled environments for yield improvement still remain untouched. Such knowledge can decisively contribute to build up correct management strategies aiming of higher productivity and to genetic breeding programs for cashew. Hence, it is imperative to quantify the extent of leaf morpho-physiological traits influencing plant performance including final yield and also to identify superior leaf traits to be used in future cashew breeding. In this study, we explored the spectrum of leaf traits mainly SLA, SLW and leaf thickness and their associations with important reproductive traits of fifteen cashew varieties in cashew orchards.

Materials and Methods

Study area, species selection and sampling design

The study area is located at cashew research plot maintained at Directorate of Cashew Research, Puttur, Karnataka, India. The climate is tropical monsoon type with high humidity and warm temperature throughout the year and most rainfall occurring from April to October. The soil types of study area are mostly lateritic and sandy clay loam soils. For the present study, we selected fifteen cashew varieties from mixed populations of cashew research plot and there were selected to cover widest variability of leaf traits in the study area (Table 1 and Fig. 1). In the month of October, 2003, the cashew materials were planted in randomized complete block layout consisting of three replicates. Each variety was represented by three entries per block and they were planted at a spacing of 5m × 5 m. Ten trees were selected for each of the fifteen cashew varieties for leaf traits measurements and other related parameters throughout the study period. They were evaluated over two productive seasons (2013-2014 and 2014-2015). For each selected variety, we collected healthy branches with fully expanded young leaves from parts of selected cashew trees. The branches were placed in plastic bags and brought to laboratory where they were submerged in water for at least 12 hr to fully rehydrate the leaves.

Leaf traits measurements

Morphological traits

Data for all the qualitative and quantitative leaf characteristics was recorded from 3^{rd} or 4^{th} fully expanded leaves of collected healthy branches for each selected trees. The observations on leaf length, leaf width, petiole length and total main veins were recorded. The leaf length was measured from apex to base of leaf lamina, leaf width was taken from broad area of leaf lamina and petiole length was measured from base of leaf lamina to pelvinus using measuring scale. Subsequently, a sub sample of the leaves was dried in an oven at 70°C for at least 48 h after which they were weighted to obtain their dry mass. Leaf area of 10 leaves was measured using portable leaf area meter. To determine fresh leaf thickness, leaf density, specific leaf weight (SLW), specific leaf area (SLA) and leaf water content (LWC), samples were collected early in the morning from 3rd /4th fully expanded fresh leaves of the selected tree species. Leaf thickness was measured between major leaf veins with a digital caliper on fresh leaves. SLW was calculated as the leaf mass to leaf area ratio and SLA as the inverse of SLW. Leaf density was calculated by dividing SLW with leaf thickness (Witkowski *et al.,* 1991). The leaf water content on fresh weight basis was calculated according to the following formula: LWC= (FW-DW)/FW where FW and DW denote fresh and dry weight respectively.

Physiological traits measurement

The chlorophylls and total carotenoids were extracted using dimethyl sulfoxide (DMSO) and acetone. The leaf samples of 100 mg was immersed in DMSO: Acetone solution (1:1) and incubated in dark for 72 hours. The supernatant was collected and absorbance was recorded at 645nm, 663nm, 652nm and 470 nm for estimation of chlorophyll a, chlorophyll b, total chlorophyll and total carotenoid using spectro photometer. The pigment contents were calculated from the equations proposed by Lichtenthaler and Buschmann (2001).

Reproductive traits measurement

Nut parameters

Data were collected on reproductive traits: nut weight, weight of whole fruit, number of hermaphrodite flowers and male flowers, flower duration, flowering intensity and sex ratio. Data on number of male flowers and number of hermaphrodite flowers were collected from 30 panicles randomly selected across the four cardinal directions of tree canopy for each cashew varieties. Number of male and hermaphrodite flowers was recorded every day till completion of flowering. Sex ratio was calculated using the formula: Sex Ratio = Total number of flowers / Number of perfect flowers. Data on kernel weight and shelling percentage were recorded from 100 nuts for each cashew varieties.
Apple characters:

Apple volume was measured by simple water displacement method.

Statistical analysis

Data were summarized and statistically analyzed using the AGRES software. General linear model ANOVA was run for each data set. The correlation analysis was used to determine relationships between traits.

Results and Discussion

Leaf morphological characters

The final size of a leaf depends on cell division and expansion. Any factor that can influence the number and size of leaf cells may affect the dimensions and size of the leaf (Tsukaya, 2003). Leaf morphological characters are important to support photosynthesis and to influence plant growth strategies in different trees (Takayoshi *et al.,* 2001). In mango, significant variation was observed in foliage density, leaf apex, leaf lamina, and colour of new and mature leaves and arrangement of major veins which can help in differentiation among cultivars (Kalyan, 2012). Leaf elongation characterizes the overall slenderness of the leaves. It reflects the integrated changes of leaf major and minor axes (Niinemets *et al.,* 2002 and 2007).

Across the studied varieties, there was strong variability in the leaf traits. Maximum leaf length and leaf width was recorded in Bhaskara. The leaf venation has important implications for leaf physiological activity and hydraulic and light-utilization efficiency. In the present study, Maddakatha-2 maintained maximum total main veins followed by Bhaskara (Table 2). Leaf thickness plays an important role in leaf and plant functioning and is related to species strategies of resource acquisition and use. The amount of light absorbed by a leaf and diffusion pathway of CO_2 through tissues depends on its thickness and density (Givnish *et al.,* 1979). In the present investigation, leaf thickness was maximum in Vengurla-4 and VTH 30/4 among cashew accessions.

The final product yield or total crop dry matter is the spatial and temporal integration of all plant processes. The photosynthetic capacity of plant and interception of solar radiation depend mostly on total leaf area. Specific leaf area (SLA) is an integration of leaf area and dry mass. It is an important parameter of growth rate because the larger the SLA, the larger the area for capturing light per unit of previously captured mass. The higher SLW indicates the higher photosynthate production, translocation and assimilation in leaves due to higher photosynthetic rate and its influence on reproductive organ and yield (Surender *et al.,* 2013). In the current study, total leaf area and SLW was maximum in VTH 30/4 and Vengurla-3 respectively (Table 2).

Associations between leaf traits

Linear correlation coefficients analysis showed variable associations between all leaf traits (Table 3). The strongest correlation is between leaf area with maximum of leaf traits (leaf length, leaf width, petiole length, leaf thickness, leaf fresh and dry weight (Figure 2). The SLA values were negatively correlated with leaf density and leaf dry weight. This supports the fact that varieties with thin leaves (low SLA values) apparently tend to have higher leaf density. Considered over all species, SLW did not show any relation with leaf thickness but it was positively related with leaf density and leaf dry weight. There was no relationship between leaf thickness and leaf density.

Our data demonstrate that SLW showed stronger dependency on leaf density with positive relationship than on leaf thickness where no significant relationship between SLW and leaf thickness observed (Table 3). However, several studies show that these two variables (SLW and leaf thickness) are positively related. This is in consistent with studies on alfalfa, soybean and Agrotis (Pammenter, 1986). Furthermore, our data also agree with those of Poorter (1998), who did not find any relationship between two variables (SLW and leaf thickness) in grass species differing in relative growth rate. These contradictory results suggest that the relationships of SLW with leaf thickness and density can show wide differences depending on the group of species (Villar R *et al.,* 2013), age and environmental conditions (Witkowski *et al.,* 1991). Here, we conclude that leaf density therefore plays major role in the determination of SLW. This could be further supported by the studies of Pammenter *et al.,*(1986) and Kebede *et al.,*(1994) where leaf dry matter content was found to be positively related to SLW. In our data, we found positive relationships between leaf dry weight and

SLW. This may be due to dependence of leaf dry weight on leaf density which in turn is related to increase in amount of cell wall surface per cell volume ratio. The effects of these two parameters on SLW have also been clearly shown in study by Witkowski (1991) in shrub species. In addition, we found no relationship between leaf thickness and leaf density indicating that across species variation is the result of different mechanisms (Niinemets *et al.*, 1999).

Light harvesting pigments

The light harvesting pigments are the main pigments involved in light capture for photosynthesis and other photochemical and non-photochemical reactions; therefore the amount of light absorbed by a leaf is related to chlorophyll content. Hence, changes in pigment content in leaves can affect photosynthesis of plants (Takayoshi *et al.*, 2001). The varieties with high chlorophyll content can produce higher biomass and increase photosynthesis (Hassan *et al.*, 2009).The chlorophyll a and total chlorophyll content was highest in Bhaskara whereas Ullal-2 had highest chlorophyll b and carotenoid content. The mean Chl a/b ratio was highest in Ullal-3 and least was in Priyanka (Table 4).

Table.1 List of the fifteen cashew varieties selected for trait measurements from the study site. The tree habit, tree spread, tree height and leaf habit are indicated

Varieties	Tree Habit	Tree spread (m)	Tree height (m)	Leaf shape	Leaf apex shape	Leaf cross section
Bhaskara	Upright & compact	8.3	6.7	Oval	Indented	Reflexed
Dhana	Upright & compact	7.5	6.5	Oval	Round	Reflexed
Kanaka	Upright & open	8.9	7.3	Oval	Indented	Incurved
Madakkathara-2	Upright & open	6.13	5.4	Oval	Indented	Reflexed
Priyanka	Upright & open	5.6	5.4	Oval	Round	Twisted
Selection -2	Upright & open	8.13	6.2	Oval	Round	Twisted
Ullal -1	Upright & open	7.4	8.2	Obovate (clubshape)	Round	Twisted
Ullal-2	Upright & open	5.8	6.3	Oval	Round	Level
Ullal-3	Upright & compact	7.5	6.7	Obovate (clubshape)	Round	Level
VRI-3	Upright & compact	4.4	5	Oval	Round	Twisted
VTH 30/4	Spreading	3.9	2.7	Obovate (clubshape)	Indented	Incurved
VTH 174	Upright & open	4.2	5.1	Oblong	Round	Level
Vengurla-1	Upright & compact	6.9	5.5	Obovate (clubshape)	Indented	Reflexed
Vengurla-3	Upright & compact	6.5	6.3	Obovate (clubshape)	Round	Reflexed
Vengurla-4	Upright & open	7.8	5.3	Oval	Round	Twisted

Table.2 Quantitative leaf morphological characters of fifteen cashew varieties. Values are mean and SE ± of 10 leaves. LL denotes leaf length (cm); LW: leaf width (cm); LR: leaf ratio (length/width); PL: petiole length; LL/PL: leaf length/petiole length; LW/PL: leaf width/petiole length; MV: main veins; LFW: leaf fresh weight (g); LDW: leaf dry weight; LA: leaf area (cm^2); SLW: specific leaf weight (mg/cm^2) and LTH: leaf thickness (µm)

Varieties	Leaf morphological traits											
	LL	LW	LR	PL	LL/PL	LW/PL	MV	LFW	LDW	LA	SLW	LTH
Bhaskara	18.0	10.5	1.72	1.60	11.29	6.57	28	2.95	1.07	98.20	10.86	290.0
Dhana	13.0	7.7	1.72	1.20	10.88	6.44	28	2.23	0.94	83.57	11.24	230.0
Kanaka	14.5	7.5	1.97	1.20	12.22	6.33	25	1.97	0.74	66.50	11.13	253.3
Madakkathara-2	12.0	8.4	1.45	1.30	9.34	6.46	29	2.53	0.98	92.63	10.56	263.3
Priyanka	16.5	9.5	1.75	1.40	11.78	6.83	23	2.66	0.90	97.73	9.21	290.0
Selection-2	16.0	9.1	1.76	1.40	11.57	6.58	24	2.24	0.85	97.60	8.75	266.7
Ullal -1	14.9	8.8	1.70	1.40	10.69	6.31	23	2.23	0.86	78.73	10.92	266.7
Ullal-2	13.0	7.9	1.64	1.20	11.15	6.73	26	1.92	0.67	60.00	11.22	240.0
Ullal-3	16.7	10.2	1.64	2.20	7.62	4.64	28	3.81	1.36	111.33	12.21	280.0
VRI-3	14.1	7.9	1.79	1.50	9.43	5.29	25	1.74	0.63	82.59	10.66	236.7
VTH 30/4	16.9	9.7	1.76	1.80	9.58	5.46	26	3.81	1.53	112.00	13.68	293.3
VTH 174	14.0	8.3	1.69	2.00	7.01	4.17	22	1.75	0.72	83.50	10.14	256.7
Vengurlla-1	12.5	7.6	1.64	1.50	8.33	5.08	23	1.84	0.87	81.53	10.71	250.0
Vengurlla-3	15.0	8.4	1.79	1.50	10.22	5.66	22	1.89	1.02	59.93	16.96	273.3
Vengurlla-4	16.0	10.4	1.54	1.60	10.01	6.53	23	3.85	1.64	99.77	16.47	300.0
SE(±)	0.4311	0.65	0.15	0.13	1.14	0.64	1.30	0.13	0.082	1.33	2.43	41.26
CD(0.05)	0.8831	1.33	0.32	0.27	2.3	1.32	2.66	0.27	0.16	2.74	4.97	84.52

Table.3 Linear correlations between leaf area (LA), specific leaf weight (SLW) and specific leaf area (SLA) with leaf morphological traits of fifteen cashew varieties.The level of significance is expressed as follows: * *P*< 0.05; ** *P*< 0.01; ns- Not significant.
FW denotes fresh weight and DW- dry weight

	SLA	**SLW**	**Leaf length**	**Leaf width**	**Petiole length**	**Leaf thickness**	**Leaf density**	**Leaf FW**	**Leaf DW**
	0.097^{ns}	-0.083^{ns}	0.669**	0.739**	0.716**	0.609**	-0.375^{ns}	0.800**	0.667**
		-0.975**	-0.117^{ns}	-0.263^{ns}	-0.168^{ns}	-0.320^{ns}	-0.912**	-0.405^{ns}	-0.626**
	-0.975**		0.161^{ns}	0.161^{ns}	0.208^{ns}	0.390^{ns}	0.904**	0.396^{ns}	0.643**

Table.4 Variation in light harvesting pigments and related parameters of fifteen cashew accessions. Values are mean and SE of fifteen cashew accessions

Accessions	Chlorophyll (mg/g FW)			Total Carotenoids (mg/g FW)	Chl a/b
	a	b	Total (a+b)		
Bhaskara	1.74	0.83	2.57	0.39	2.1
Dhana	1.35	0.86	2.20	0.37	1.6
Kanaka	0.93	0.92	1.85	0.39	1.0
Madakkathara-2	1.41	0.87	2.28	0.38	1.6
Priyanka	1.29	1.09	2.38	0.39	1.2
Selection-2	1.63	0.89	2.52	0.42	1.8
Ullal -1	1.57	0.77	2.33	0.38	2.0
Ullal-2	1.43	0.98	2.41	0.41	1.5
Ullal-3	1.50	0.44	1.94	0.37	3.4
VRI-3	1.63	0.65	2.28	0.40	2.5
VTH 30/4	1.55	0.87	2.41	0.40	1.8
VTH 174	1.57	0.74	2.31	0.38	2.1
Vengurlla-1	1.62	0.90	2.52	0.39	1.8
Vengurlla-3	1.48	0.52	2.00	0.41	2.8
Vengurlla-4	1.70	0.67	2.36	0.41	2.5
SE±	0.0488	0.1197	0.1058	0.054	0.59
CD (0.05)	0.0999	0.2451	0.2167	0.110	1.22

Table.7 Phenotypic correlation coefficients among 12 reproductive traits of fifteen cashew varieties. The level of significance is expressed as follows: * P< 0.05, ** P< 0.01. PPT: panicle per tree; MF: male flower; HF: hermaphrodite flower; SR: sex ratio; PFP: pollen fertility percentage; FI: flowering intensity; DFA: days to flower anthesis; NNT: nuts per tree; NWT: nut weight/tree; NYT: nut yield in kg/tree; KWT: kernel wt (g) and SP: shelling percentage

	PPT	**MF**	**HF**	**SR**	**PFP**	**FI**	**DFA**	**NNT**	**NWT**	**NYT**	**KWT**
PPT	1.000	0.278	-0.535*	-0.482*	-0.040	-0.037	0.244	0.741**	-0.116	0.671**	-0.315
MF		1.000	-0.110	-0.860**	-0.156	0.298	0.486*	0.049	-0.361	0.085	-0.550*
HF			1.000	0.595**	0.569*	0.372	-0.469*	0.645**	-0.445*	0.756**	0.129
SR				1.000	0.445*	-0.060	-0.428	-0.146	0.338	-0.467*	0.489*
PFP					1.000	0.389	-0.522*	0.521*	0.010	0.444*	-0.102
FI						1.000	0.125	-0.452*	-0.112	0.565*	-0.383
DFA							1.000	-0.456*	-0.221	-0.546*	-0.551*
NNT								1.000	-0.592**	0.645**	0.003
NWT									1.000	-0.004	0.806**
NYT										1.000	-0.226
KWT											1.000
SP											

Table.5 Variation in flowering parameters of fifteen cashew accessions. Values are mean and SE of fifteen cashew accessions. HFL denotes hermaphrodite flower; MFL: male flower; SR: sex ratio; FLL: flowering laterals and TPT: total flowering panicle

Varieties	Flowering traits				
	HFL	MFL	SR	FLL	TPT
Bhaskara	97	217	0.31	27	180
Dhana	75	232	0.24	26	230
Kanaka	98	293	0.25	18	212
Madakkathara-2	81	223	0.27	20	242
Priyanka	94	199	0.32	26	203
Selection-2	98	262	0.27	28	198
Ullal -1	96	208	0.32	32	187
Ullal-2	96	179	0.35	20	186
Ullal-3	98	180	0.35	21	235
VRI-3	84	224	0.27	27	230
VTH 30/4	89	245	0.27	28	254
VTH 174	84	260	0.25	30	247
Vengurll-1	92	220	0.30	26	198
Vengurlla-3	91	244	0.27	26	223
Vengurlla-4	93	235	0.28	30	256
SE±	0.78	1.62	0.0043	1.76	1.90
CD (0.05)	1.60	3.33	0.0087	3.62	3.91

Table.8 Linear correlations between reproductive traits with leaf traits and canopy characters in cashew. The level of significance is expressed as follows: * *P*< 0.05, ** *P*< 0.01. PPT: panicle per tree; HF: hermaphrodite flower; SR: sex ratio; PFP: pollen fertility percentage; FI: flowering intensity; NNT: nut number per tree; NWT: nut weight; NYT: nut yield in kg per tree ; LL: leaf length; LW: leaf width; LTh: leaf thickness; LD: leaf duration; LA: leaf area; SLA: specific leaf area; SLW: specific leaf weight; MS: Main shoot; LS: lateral shoot; TL: total leaves for lateral shoots; FP: flowering panicle

	LL	**LW**	**LTh**	**LD**	**LA**	**SLA**	**SLW**	**MS**	**LS**	**TL**	**FP**
PPT	0.045	0.159	0.155	0.413	0.364	-0.461*	0.459*	0.218	0.563*	0.540*	0.333
HF	0.501*	0.391	0.431	-0.190	0.011	0.026	0.016	0.262	0.076	-0.093	0.042
SR	0.312	0.346	0.267	-0.185	0.112	0.026	-0.068	-0.064	0.016	-0.150	-0.053
PFP	0.342	0.385	0.511*	-0.101	0.138	-0.111	0.144	0.369	0.217	0.371	0.221
FI	0.586*	0.379	0.270	-0.194	0.314	0.017	-0.049	0.635**	0.197	0.523*	0.644**
NNT	0.348	0.423	0.393	0.335	0.538*	-0.469*	0.483*	0.295	0.591*	0.513*	0.359
NWT	0.493*	0.460*	0.558*	-0.277	0.449*	0.090	0.447*	-0.269	0.004	-0.007	-0.133
NYT	0.450*	0.527*	0.518*	-0.115	0.464*	-0.146	0.522*	0.681**	0.443*	0.469*	0.453*

Table.6 Variation in apple and nut traits of fifteen cashew accessions. Values are mean and SE of fifteen cashew accessions. NNT: nuts per tree; NWT: nut weight/tree; NYT: nut yield in kg/tree; KWT: kernel wt (g) and SP: shelling percentage, AWT: apple fresh wt (g); AV: apple volume (ml)

Varieties	Apple and nut traits						
	AWT	AVL	NNT	NWT	NYLD	KWT	SHP
Bhaskara	71.60	81.7	152	6.93	8.96	2.7	29.9
Dhana	71.70	71.7	174	7.00	5.67	2.2	29.3
Kanaka	58.70	78.3	162	5.90	6.49	1.9	30.2
Madakkathara-2	81.63	86.7	180	8.17	8.74	2.3	31.9
Priyanka	94.91	118.3	172	8.83	7.33	2.9	30.2
Selection-2	69.77	76.7	158	7.27	7.53	1.6	24.1
Ullal -1	58.40	65.0	174	7.60	9.18	2.1	30.9
Ullal-2	65.63	73.3	115	6.30	7.23	2	32.8
Ullal-3	65.97	81.7	220	7.80	8.65	2.3	31.5
VRI-3	64.33	70.0	189	6.53	5.51	1.87	27.0
VTH 30/4	83.00	88.3	192	7.10	8.60	1.7	24.1
VTH 174	76.83	93.3	178	5.97	7.60	1.4	27.3
Vengurlla-1	53.27	60.0	167	5.03	5.38	1.9	32.2
Vengurlla-3	69.60	83.3	187	6.07	7.15	2.1	26.9
Vengurlla-4	73.07	90.0	213	6.60	8.22	2.1	30.4
SE±	13.37	1.09	2.04	0.37	0.28	0.16	0.65
CD (0.05)	27.39	2.23	4.19	0.76	0.57	0.34	1.81

Figure.1 Tree morphology of cashew varieties. 1A. Tree habit: a: Upright and compact, b: Upright and open and c: Spreading; 1B. Branching pattern: a: Extensive and b. intensive. At the study site, the above tree characters were photographed and presented to show the tree habit and branching pattern of selected cashew varieties

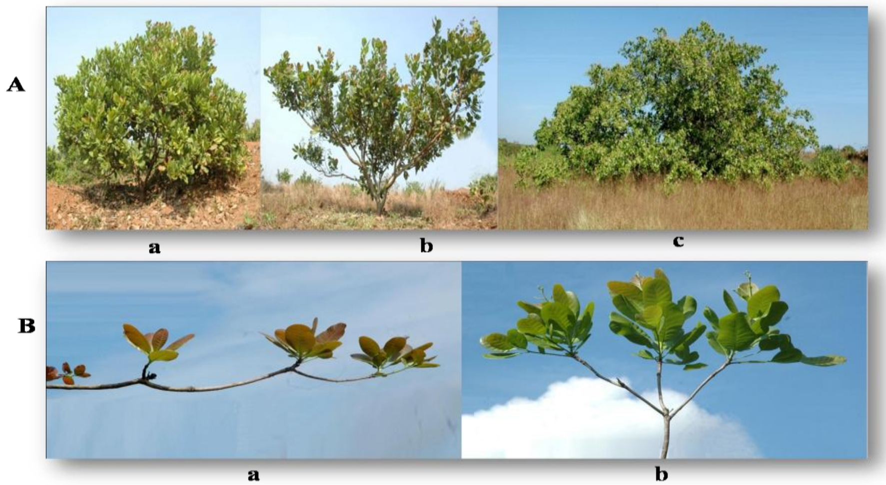

Figure.2 Association between individual leaf area and leaf morphological traits. A. leaf area with leaf length (cm), B. with leaf width (cm) , C. with petiole length (cm) D. with leaf dry weight (cm) and E. with leaf thickness (µm). The level of significance is expressed as follows: * *P*< 0.05; ** *P*< 0.01

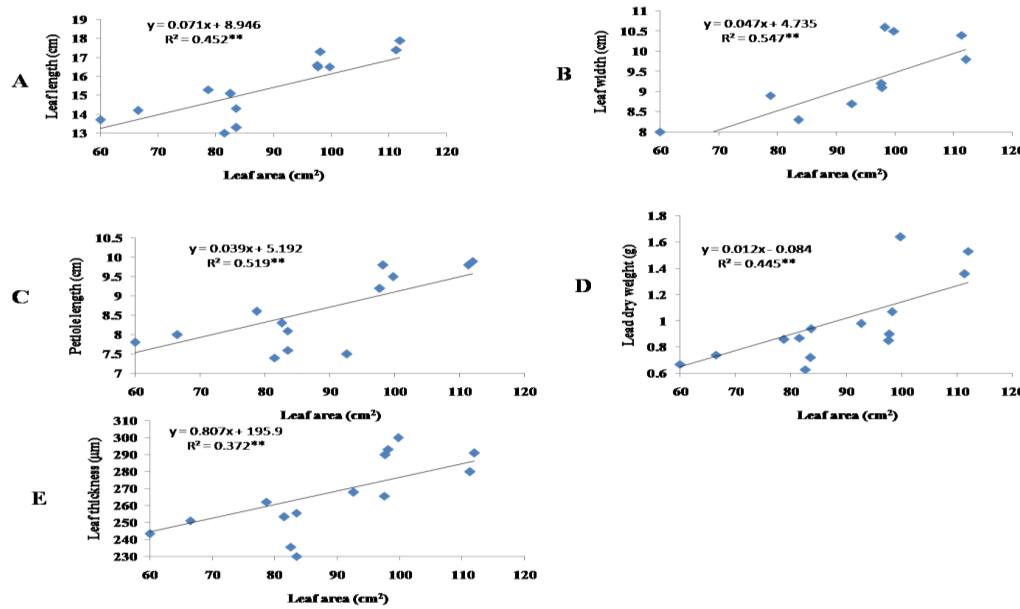

Figure.3 Flowering characteristics of cashew varieties observed at study site. 3A. Types of flowering: A: Fresh hermaphrodite flower, A_1: Old hermaphrodite flower, B: Fresh male flower, B_1: Old male flower, C: Flower bud and D: Immature nut in initial stage; 3B. Shape of panicle/inflorescence: Narrowly pyramidal, Pyramidal and broadly pyramidal; 3C: Color of flowering panicle: white, cream and Pink

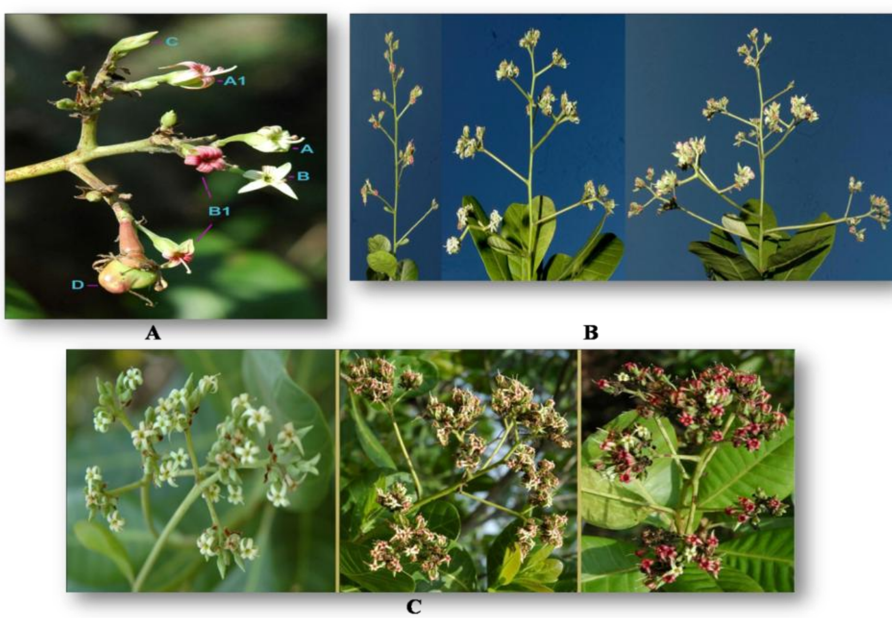

Figure.4 Variation in nut characters of cashew accessions at harvest stage

Reproductive parameters

The present study was aimed to evaluate the reproductive parameters of cashew accessions. Flowering traits viz., hermaphrodite flower, male flower, flowering laterals and total flowering panicle were recorded. Kanaka, Selection- 2 and Ullal-3 had highest number of hermaphrodite flowers and least was recorded in Dhana. Flowering laterals and total flowering panicle were maximum in Ullal-2 and vengurlla-4 (Table 5). There was variation in apple and nut characters among cashew accessions. Apple weight and apple volume was highest in Priyanka whereas Ullal-1 recorded lowest apple weight and apple volume respectively. Among the nut traits recorded, nut weight and kernel weight was highest in Priyanka AND Ullal-1 and Ullal-2 had highest nut yield and shelling percentage (Table 6).

The summary of the phenotypic correlations among 12 reproductive traits is presented in Table 7, Figure 3 and 4. The highest positive correlations were found between nut yield and nuts per tree. The results showed that panicle per tree, hermaphrodite flower, nuts per tree, nut yield and pollen fertility percentage were positively correlated with each other. Male flower, hermaphrodite flower and sex ratio were negatively correlated with kernel weight, nut weight and nut yield. Days to flower anthesis showed negative relationships with flower intensity while it was positive association with nut yield. Association between nut weight and nut yield was insignificant. Here, we found positively and highly significant relationships among nuts per tree, hermaphrodite flowers per panicle, pollen grain fertility and nut yield. These results are in accordance with reports of Rao (1974) and Murthy *et al.,*(1984). Therefore, improvement in cashew nut yield can be achieved through selection of these highly correlated characters (Adams *et al.,* 1967). The insignificant relationships between nut weight and nut yield found in this study indicate that yield improvement through direct selection of nut weight as a single character would be impractical. Our study was contrary to the negatively significant associations between nut weight and nut yield reported by Northwood *et al.,*(1966). But similar negative significant influence of nut weight on nuts per tree was found in our study (Table 7).

Associations between eight reproductive traits with leaf traits also differed significantly (Table 8). Among leaf traits studied, leaf length, leaf width, leaf thickness, LA, SLA and SLW showed significant relationships with reproductive traits. There were significant and positive associations between hermaphrodite flower, flower intensity, nut weight and nut yield with leaf length; nut weight and nut yield with leaf width; pollen fertility percentage, nut weight and nut yield with leaf thickness; nuts per tree, nut weight and nut yield with LA and pollen fertility percentage with SLW respectively. In contrast, pollen fertility percentage and nut per tree were correlated negatively with SLA values. Significant relationships between leaf length, leaf width, leaf thickness and leaf area with nut yield suggest that leaf surface area plays significant role in dry matter production during fruit development and varieties with larger leaves tend to produce large fruit (Aliyu, 2004). Such studies concurs our data where we found significant relationships between these traits with nut yield. The influence of relationships between these leaf traits and nut yield would be better amplified by nut weight as shown in Table 8. Knowledge of complex relationships between nut weight and nut yield would be essential to develop cashew varieties that combine moderately high yielding and good kernel quality. In our study, correlation analysis revealed direct significant effect of nut weight on kernel weight.

In conclusion, our results confirm that leaf traits such as leaf thickness, SLA and SLW could be regarded as primary yield attributing traits to improve nut yield in cashew. The significant association between LA and SLW with yield components (nuts per tree, nut weight and nut yield) indicates higher photosynthetic surface area available for production, translocation and distribution of photosynthates in leaves which influence development of reproductive organ and yield. Finally we conclude that variations in leaf morphology through changes in physiological parameters can act as best candidate for screening cashew varieties to improve cashew nut yield.

References

ADAMS, MW. 1967. Basis of yield component compensation in crop plants with special reference to the field bean, *Phaseolus vulgaris*. Crop Science **7**: 505–510

ALIYU, O M. 2004. Characterization and compatibility studies in cashew (*Anacardium occidentale* L.). Ph. D.Thesis, University of Ilorin, Ilorin, Nigeria

Araus, J.L., Amaro, T., Zuhair, Y., Nachit, M.M. 1997. Effect of leaf structure and water status on carbon isotope discrimination in field-grown durum wheat. Plant Cell Environ. 20: 1484-1494

Bort, J., Araus, J.L., Hazzam, H., Grando, S., Ceccarelli, S. 1998. Relationships between early vigour, grain yield, leaf structure and stable isotope composition in field grown barley. *Plant Physiol. Biochem*. 36: 889-897

Campbell, R.J., Mobley, K.N., Marini, R.P., Pfeiffer, D.G. 1990.Growing conditions alter the relationship between SPAD-501 values and apple leaf chlorophyll. *Hortscience.* 25: 330-331

Chacko EK, Baker I, Downton JWS. 1990. Towards a sustainable cashew industry for Australia. *J. Aust. Inst. Agric. Sci*.3: 39-43

Coley, P.D.1988. Effects of plant growth rate and leaf lifetime on the amount and type of anti-herbivore defense. *Oecologia*. 74:531–536

FAO. 2008. Food and Agriculture

Organization of the United Nations, Crop Production Statistics Division. http:// faostat.fao.org/site/567/Desktop Default.aspx?PageID=567. website last visited 19th June 2010

Fotovat, R., Valizadeh, M., Toorchi, M. 2007. Association between water-use efficiency components and total chlorophyll content (SPAD) in wheat (*Triticum aestivum* L.) under well-watered and drought stress conditions. J. Food Agr. Environ. 5: 225-227

Gáborčík, N. 2003. Relationship between contents of chlorophyll (*a*+*b*) (SPAD values) and nitrogen of some temperate grasses. Photosynthetica 41: 285-287

Garnier, E. and Laurent, G. 1994. Leaf anatomy, specific mass and water content in congeneric annual and perennial grass species. *New Phytologist* 128: 725–736

Givnish T. 1979. On the adaptative significance of leaf form. In: Solbrig OT, Jain S, Johnson GB, Raven PH (eds) Topics in plant population biology. Columbia University Press, New York, pp 375–407

Grime JP., Thompson K., Hunt R., Hodgson JG., Cornelissen JHC. 1997. Integrated screening validates primary axes of specialization in plants. *Oikos* 79: 259–281

Hassan, M.S., Khair, A., Haque, M.M., Azad, A.K., Hamid, A., 2009. Genotypic variation in traditional rice varieties for chlorophyll content, SPAD value and nitrogen use efficiency. Bangladesh J. Agric. Res. 34, 505–515

Kalyan, C., Tuhinsri, S., Arvind, K.C., Samir, K.S., 2012. Leaf characters and measurements of mango cultivars in Gangetic plains of West Bengal. In: International Seminar on Multidisciplinary Approaches in Angiosperm Systematics, 12 September 2012, Kalyani, WB, pp. 762–768

Kebede H.Martin B, Nienbuis J, King G. 1994. Leaf anatomy of t\vo Lycopersicon species vMth contrasting gas exchange properties. Crop Science 34; 108-1 13

Mneney EE., Mantell SH., Bennett M. 2001. Use of random amplified polymorphic DNA (RAPD) markers to reveal genetic diversity within and between populations of cashew (*Anacardium occidentale* L.). *J. Hortic. Sci. Biotechnol*. 76: 375-383

Murthy, KN., KK, Vijaya, R.S N, Pillai and PM, Kumaran.1984. Flowering behaviour and correlation studies in cashew. *In:* Abstract of Proceedings of the International Cashew Symposium, Cochin, Kerala, India. 12–15 March 1979

Nageswara Rao, R.C., Talwar, H.S., Wright, G.C. 2001. Rapid assessment of specific leaf area and leaf nitrogen in peanut (*Arachis hypogaea* L.) using a chlorophyll meter. *J. Agron. Crop Sci*. 186: 175-182

Niinemets U. 1999. Components of leaf dry mass per area, thickness and density alter leaf photosynthetic capacity in reverse directions in woody plants. *New Phytologist*. 144: 35–47

Niinemets Ü., Fleck S. 2002. Petiole mechanics, leaf inclination, morphology, and investment in support in relation to light availability in the canopy of *Liriodendron tulipifera. Oecologia.* 132: 21–33

Niinemets Ü., Portsmuth A., Tobias M. 2007. Leaf shape and venation pattern alter the support investments within leaf lamina in temperate species: a neglected source of leaf physiological differentiation? *Functional Ecology*. 21:28–40

Northwood, PJ.1966. Some observations of flowering and fruit-setting in cashew (*Anacardium occidentale* L.). *Tropical Agriculture* 43: 35–24

Oren, R.., Schulze, E.D., Matyssek, R. and Zimmermann, R. 1986. Estimating photosynthetic rate and annual carbon gain in conifers from specific leaf weight and leaf biomass. *Oecologia*.70: 178–193

Pammenter NW., Drennan PM., Smith VR. 1986. Physiological and anatomical aspects of photosynthesis of two Agrostis species at a sub-antarctic island. New Phytologist. 102: 143–16

Parameswaran NK, Daramodaran VK, Prabhakaran PV. 1984. Factors influencing yield in cashew (*Anacardium occidentale* L). *Indian Cashew* J. 16: 15-19

Patnaik HP, Das MS, Panda JM. 1985. Studies on fruit set and fruit drop in cashew (*Anacardium occidentale* L.) under Orissa conditions. *Cashew Causerie* 7: 7-8

Peng, S., Krieg, D.R. and Girma, F.S. (1991). Leaf photosynthetic rate is correlated with biomass and grain production in sorghum lines. *Photosynthesis Research*. 28: 1-7

Poorter H., Van der Werf A.1998. Is inherent variation in RGR determined by LAR at low irradiance and by NAR at high irradiance? A review of herbaceous species. In: Lambers H.,

Rao, V N M.1974. Crop Improvement of Cashew. Report All India Summer Institute on Improvement and Management of Plantation Crops, Mimeographed, 128–134

Subbaiah. 1983. Fruiting and abscission patterns in cashew. The J. of Agri. Sci. 100: 423-427

Surendar, K.K., Rajendran, V., Durga Devi, D., Jeyakumar, P., Ravi, I., Velayudham, K., 2013. Impact of water deficit on growth attributes and yields of banana cultivars and hybrids. *Afr. J. Agric. Res*. 8: 6116–6125

Takayoshi, K., Mitsutoshi, K., Yutaka, A., Shigeta, M., Thomas, T.L., 2001. Leaf morphology and photosynthetic adjustments among deciduous broad-leaved trees within the vertical canopy profile. Tree Physiol. 21: 951–958

TSUKAYA H., 2003. Organ shape and size: a lesson from studies of leaf morphogenesis. *Current Opinion in Plant Biology*. 6: 57–62

Villar R., Ruiz-Robleto J., Ubera JL., Poorter H. 2013. Exploring variation in leaf mass per area (LMA) from leaf to cell: An anatomical analysis of 26 woody species. American J. of Bot. 100: 1969– 1980

Witkowski ETF., Lamont BB. 1991. Leaf specific mass confounds leaf density and thickness. *Oecologia* 88: 486–493

How to cite this article:

Babli Mog and Nayak, M.G. 2018. Leaf Morphological and Physiological Traits and Their Significance in Yield Improvement of Fifteen Cashew Varieties in West Coast Region of Karnataka, India. *Int.J.Curr.Microbiol.App.Sci.* 7(07): 1455-1469.
doi: https://doi.org/10.20546/ijcmas.2018.707.173