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RESEARCH ARTICLE

Determination of linear model for coffee leaf area measurement

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Abstract

The present study was conducted with the objective to develop linear model for coffee leaf area measurement. Leaves were collected from 47 coffee cultivars that were field planted at Mechara Agricultural Research Center, West Harerge Zone, in July 2005 and are currently under evaluation. For leaf sample collection, four plants were randomly selected for each of the 47 cultivars from eastern Ethiopia. Five normal leaves were detached from each sample plant and used for data collection. Variation among constant factor (K) of the coffee cultivars was determined using R^2 value in both linear and logarithmic regression. The result of the study revealed that leaf area parameters were highly and positive correlation (from 0.90 to 0.95 at $P<0.01$). K value for leaf area measurement varied from 0.45 to 0.89 and with mean value of 0.68. The R^2 values of 47 constant factor (K) of the 47 coffee cultivars was 0.002 in linear regression and 0.0008 in logarithmic regression and was negligible. Hence, mean value of 0.68 can be used as K along with leaf length and leaf width for coffee leaf area determination. LA= 0.68*LL*LW (where LA is leaf area, LL- leaf length and LW- leaf width) is recommended for coffee leaf area measurement. The information generated through this investigation may be useful for the coffee breeders to develop suitable coffee varieties and in deciding breeding strategy for the coffee breeding programme.

Key words: Arabica coffee, constant factor, leaf area, linear model

Introduction

Coffee is a major cash crop in Ethiopia. In 2018, the country earned 839 million dollar from coffee export accounting for close to 30% income generated from all export commodities (NBE, 2019). It is a means of livelihood for about 25 million people in the country. Ethiopia is the center of origin and diversity for Arabica coffee (Bayeta *et al.*, 2007). The country ranks 5th from world and 1st from Africa in coffee production (FAO, 2020). Coffee research in Ethiopia was started in 1960s. So far, 40 (34 pure line and 6 hybrid) coffee varieties were released for production in different parts of the country. Leaf area measurement is an important task in coffee breeding. Coffee leaf area can be measured using leaf area meter by scanning the leaf, using square paper (1cmx1cm) and linear model where constant factor is used along with leaf length and leaf width. Although leaf area meter is accurate, the leaves should be detached from the plant for measurement. The equipment is expensive and hence not available in the majority of coffee research centers in the country. Square paper method is also accurate but it is laborious and time consuming. Hence,

square paper method is not helpful whenever leaf area is measured for large number of coffee cultivars. Information is scanty on constant factor (K) to be used along with leaf length and leaf width for leaf area determination. Linear model of leaf area measurement is fast, less costly and nondestructive method unlike leaf area meter and square paper method. This study was conducted with the objective to develop linear model for coffee leaf area measurement.

Materials and methods

Total of 47 coffee cultivars from eastern Ethiopia were used for the study. The cultivars were field planted at Mechara Agricultural Research Center in July 2005 using 7x7 simple lattice design with two replications. Two cultivars (H618/98 and 74110) were included to fulfill the design and as check, respectively. The later one is from south West Ethiopia in origin. Spacing between rows was 3m and between plants was 2m. A single row (plot) consisted of eight trees. For leaf sample collection, four plants (2 from each replication) were randomly selected for each of the 47 cultivars from eastern Ethiopia. Then, five normal leaves (excluding 3 nodes from the terminal bud as per recommended) were detached from each sample plant. As a result, total of 940 leaves were detached and taken to lab for study. Data collected were leaf length, leaf width and actual leaf area. We used notations like LA is leaf area, LL for leaf length and LW for leaf width. Leaf length (cm) was measured from petiole end to apex of a leaf using ruler; leaf width (cm) was measured at the widest part of leaves using same measurement tool and finally actual leaf area (cm^2) was measured using square paper. Each sample leaf was placed on square paper (1cmx1cm), was drown and determined. The collected data were analyzed to determine range of values, mean, standard error, correlation between leaf parameters. Constant factor (K) for leaf area was determined from leaf length, leaf width and actual leaf area. The value was determined using the formula: K= (LA/ (LL*LW)), where K, LA, LL and LW are Constant factor for leaf area determination, leaf area, leaf length and leaf width in that order. The degree of variation among constant factor (K) of the coffee cultivars was determined using R^2 value in both linear and log methods.

Results and discussion

Leaf length, leaf width and actual leaf area varied from 9.16 to 18.43 cm, 3.82 to 8.77 cm and 28.76 to 105.45 cm^2, respectively (Table1). The mean values of the three characters were 13.50 cm, 6.32 cm, and 58.96 cm^2 in that order. Both leaf length and leaf width were highly and positive correlated with leaf area and with each other depicted in Table 2. The degree of association/ between leaf length and leaf area was the highest (r=0.95**) followed by leaf width (r=0.90**). The constant factor (K) for leaf area measurement varied from 0.45 to 0.89 with mean value of 0.68 and standard deviation of 0.07. In recent studies, Cavallaro *et al.*, (2020) who developed mathematical model for leaf area measurement using 160 leaves from Arabica Catuaí 144 Vermelho in Brazil recommended 0.64 as constant factor for leaf area determination. Catura is a mutant type of Arabica coffee. Leaf area estimation models were developed for different crops in different countries. The estimation models were developed for cucumber (Blanco and Folegatti, 2005), sweet potato (Eko *et al.*, 2019), sunflower (Rouphae *et al.*, 2007), apple (Sala *et al.*, 2015), ginger (Anteneh *et al.*, 2008), Jatropha (Pompelli *et al.*, 2012) and rose (Rouphael et al, 2010). In recent study, Cavallaro *et al.*, (2020) who developed mathematical model for coffee leaf area measurement using 160 leaves from Arabica Catuaí 144 Vermelho in Brazil recommended 0.64 as constant factor for leaf area determination. Catura is a mutant type of Arabica coffee.

Table1: Mean values of leaf area component by coffee genotype

S. No.	Genotype	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	S. No.	Genotype	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)
1	H01/04	9.16	3.91	28.76	27	H28/04	13.84	5.86	59.28
2	H02/04	13.33	6.43	57.58	28	H29/04	13.23	6.07	59.43
3	H03/04	12.42	6.38	35.47	29	H30/04	12.20	6.84	55.49
4	H04/04	15.10	6.68	63.24	30	H31/04	12.94	5.55	51.26
5	H05/04	14.99	6.84	65.78	31	H32/04	11.39	5.03	35.04
6	H06/04	13.42	5.90	52.73	32	H33/04	12.94	5.89	51.79
7	H07/04	11.85	5.03	50.90	33	H34/04	15.16	7.00	75.60
8	H08/04	10.44	4.53	34.59	34	H35/04	13.61	5.55	58.82
9	H09/04	13.35	6.58	57.62	35	H36/04	12.98	6.00	60.19
10	H11/04	12.51	6.08	50.12	36	H37/04	13.53	6.76	70.07
11	H12/04	13.94	6.44	56.42	37	H38/04	12.99	6.27	53.18
12	H13/04	13.88	7.13	68.21	38	H39/04	12.85	7.01	60.82
13	H14/04	11.55	5.11	44.26	39	H40/04	15.76	7.39	78.82
14	H15/04	9.65	3.82	32.84	40	H41/04	14.86	6.86	63.05
15	H16/04	12.75	6.24	50.32	41	H42/04	11.65	5.08	41.58
16	H17/04	13.55	6.27	57.25	42	H43/04	14.00	6.37	63.64
17	H18/04	13.02	6.02	50.98	43	H44/04	14.63	7.13	66.67
18	H19/04	17.73	7.96	93.52	44	H45/04	14.00	6.45	57.70
19	H20/04	15.92	7.98	81.66	45	H46/04	14.10	7.09	65.75
20	H21/04	14.43	6.42	66.19	46	H47/04	12.73	6.37	54.08
21	H22/04	13.74	6.44	65.08	47	H48/04	15.23	7.59	73.59
22	H23/04	13.56	6.83	60.61		**Minimum**	***9.16***	***3.82***	***28.76***
23	H24/04	18.43	8.77	105.45		**Maximum**	***18.43***	***8.77***	***105.45***
24	H25/04	12.28	5.86	43.35		**Mean**	***13.50***	***6.32***	***58.96***
26	H27/04	12.61	5.66	42.95		**SD**	***1.75***	***0.98***	***15.24***

Similarly Walyaro (1983) suggested 0.88 for leaf area determination. The deviation of their result from my study is probably due to the difference in genotypes. Conversely, the current finding is in agreement with Yacob *et al.*, (1993) who conducted leaf area estimation in CBD resistant Coffea Arabica suggested 0.70 as constant factor to be used along with leaf length and width for leaf area estimation. Moreover, the R^2 values of constant factors (Ks) of the 47 coffee cultivars in the current study was 0.002 in linear regression and 0.0008 in logarithmic regression as depicted in Fig 1 and 2. This implies that mean value of 0.68 can be used along with leaf length and leaf width for leaf area determination. Hence, LA= 0.68*LL*LW (where LA is leaf area, LL- leaf length and LW- leaf width) is the recommended linear model for coffee leaf area measurement.

Table2: Correlation coefficients among leaf parameters

Traits	Leaf length	Leaf width	Leaf area
Leaf length		0.91**	0.95**
Leaf width			0.90**
Actual Leaf area			

Note: * significant (P<0.05) and ** highly significant (P<0.01)

Table 3: Constant factor (K) for leaf area determined from leaf length, width, and actual leaf area

S.No.	Genotype	K	S.No.	Genotype	K	S.No.	Genotype	K	S.No.	Genotype	K
1	H01/04	0.80	14	H15/04	0.89	27	H28/04	0.73	40	H41/04	0.62
2	H02/04	0.67	15	H16/04	0.63	28	H29/04	0.74	41	H42/04	0.70
3	H03/04	0.45	16	H17/04	0.67	29	H30/04	0.66	42	H43/04	0.71
4	H04/04	0.69	17	H18/04	0.65	30	H31/04	0.71	43	H44/04	0.64
5	H05/04	0.64	18	H19/04	0.66	31	H32/04	0.61	44	H45/04	0.64
6	H06/04	0.67	19	H20/04	0.64	32	H33/04	0.68	45	H46/04	0.66
7	H07/04	0.85	20	H21/04	0.71	33	H34/04	0.71	46	H47/04	0.67
8	H08/04	0.73	21	H22/04	0.74	34	H35/04	0.78	47	H48/04	0.64
9	H09/04	0.66	22	H23/04	0.65	35	H36/04	0.77		**Mean**	**0.68**
10	H11/04	0.66	23	H24/04	0.65	36	H37/04	0.77		**Stdev**	**0.07**
11	H12/04	0.63	24	H25/04	0.60	37	H38/04	0.65			
12	H13/04	0.69	25	H26/04	0.70	38	H39/04	0.68			

Figure1: Linear regression among constant factors (Ks) for leaf area estimation

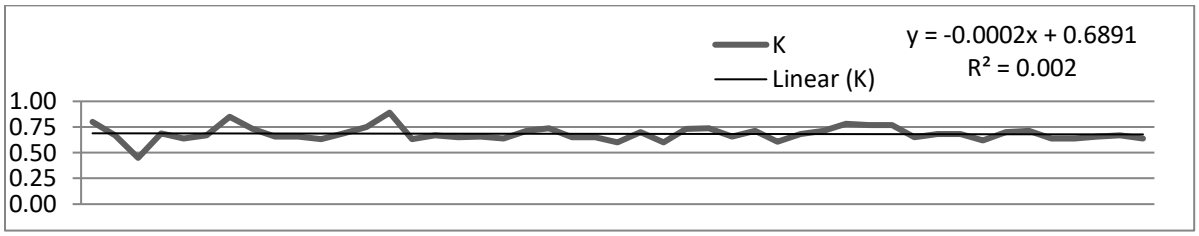
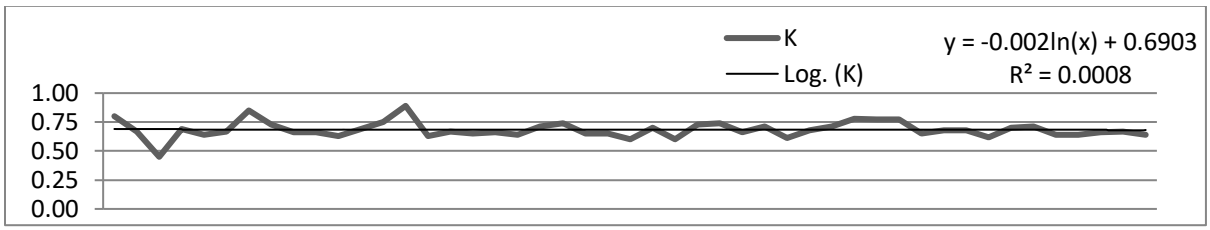


Figure 2: Logarithimc regression among constant factors (Ks) for leaf area estimation



Conclusion

Linear model of leaf area measurement is nondestructive, fast and less costly. There is strong and positive correlation among leaf parameters (Leaf length, leaf width and leaf area) with correlation coffecient value of 0.9 to 0.95 (at $P<0.01$). Constant factor (K) for leaf area measurement ranged from 0.45 to 0.89 and with mean value of 0.68. The R^2 value of all constant factors (Ks) was 0.002 in linear regression and 0.0008 in logarithmic regression and was negligible. Hence, mean value of 0.68 can be used as constant factor (K) along with leaf length and leaf width for coffee leaf area determination. Accordingly, LA= 0.68*LL*LW (where LA is leaf area, LL- leaf length and LW-leaf width) is recommended for coffee leaf area measurement. It is advisable to consider age of the plant and growth habit of the cultivars in future work.

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