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Correlation and path analysis in Kalmegh (*Andrographis paniculata* Nees.)

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Abstract
Correlation coefficient and Path coefficient analysis was studied in six lines *viz.*, IIHR AP 25-4 (L_1), IIHR AP 32-1 (L_2), IC111295 (L_3), IIHR AP 18-7 (L_4), IIHR AP 30-8 (L_5), IIHR AP 18-4 (L_6) which were crossed with three testers *viz.*, Anand Kalmegh-1 (T_1), IIHR AP 27-2 (T_2) and IC111291 (T_3) and the 18 hybrids obtained through line x tester mating design. They were evaluated for the important quantitative traits related to herbage yield and andrographolide yield per plant. Correlation results revealed that leaf andrographolide yield per plant exhibited highly significant positive association with leaf area index and number of leaves per plant. Stem andrographolide yield per plant recorded highly positive significant association with stem dry weight and total dry weight per plant. Path analysis showed that leaf andrographolide yield and stem andrographolide yield per plant were directly contributing to total andrographolide yield per plant.

Keywords: Correlation coefficient analysis, Path analysis, Kalmegh, *Andrographis paniculata*

Introduction
Kalmegh (*Andrographis paniculata* (Wall. ex Nees) is one of the important medicinal plants of family Acanthaceae and known as "king of bitters" in English. It finds mention in various forms in Indian, Chinese, Malay, Thai, Unani, and Japanese systems of medicine. It has been used for centuries in Asia to treat gastro-intestinal and upper respiratory infections, fever, herpes, sore throat, and a variety of other chronic and infectious diseases [1]. The major chemical compounds present are di-terpenoids and flavonoids. Diterpenic constituents present in *A. panicultata* are andrographolide, 14-deoxy-11, 12-didehydroandrographolide, 14-deoxyandrographolide, 3,14-dideoxyandrographolide, 14-deoxy-12-hydroxyandrographolide, neoandrograholide, 14-deoxyandrographolide. Andrographolide ($C_{20}H_{30}O_5$) is the major diterpenoid in *A. paniculata*, making up about 4%, 0.8-1.2% and 0.5-6% in dried whole plant, stem and leaf extracts respectively. Andrographolide is abundant in leaves and can be easily isolated from the crude plant extracts as crystalline solid [2].
In the present study, line x tester mating is carried out among the selected parents and hybrid progenies developed by so were subjected for correlation and path coefficient analysis to study the relationship between different quantitative traits.

Material and Methods
The research work was carried out at experimental fields of Division of floriculture and medicinal crops, Indian Institute of Horticultural Research, Bengaluru, Karnataka during the year 2016 – 17. The experimental material consists of six lines and three testers (Table 1) and 18 hybrid combinations obtained by crossing them in Line x Tester mating design. Twelve important quantitative traits *viz.*, plant height, plant spread, number of primary branches per plant, number of secondary branches per plant, leaf area index, number of leaves at harvest per plant, leaf dry weight per plant, stem dry weight per plant, total dry weight per plant, leaf andrographolide yield per plant, stem andrographolide yield per plant and total andrographolide yield per plant were estimated.

Table 1: Kalmegh parents taken for the present study

	Line / Tester	Name of the parent
1.	L_1	IIHR AP 25-4
2.	L_2	IIHR AP 32-1
3.	L_3	IC111295
4.	L_4	IIHR AP 18-7
5.	L_5	IIHR AP 30-8
6.	L_6	IIHR AP 18-4
7.	T_1	Anand Kalmegh-1
8.	T_2	IIHR AP 27-2
9.	T_3	IC111291

Estimation of correlation coefficient

Correlation coefficient analysis measures the mutual relationship between various characters at genotypic (g), phenotypic (p) and environmental levels and was estimated with the help of formula suggested by Miller *et al*. (1958) [3].

Path coefficient analysis

Path coefficient analysis splits the genotypic correlation coefficient into measure of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable. Path coefficient analysis was carried out following Dewey and Lu (1959) [4].

The result of path coefficient analysis is interpreted as per the scale suggested by Lenka and Misra (1973) [5].

Results and discussion

Correlation

Correlation coefficients for herbage yield, andrographolide content and their components in kalmegh is given in Table 2.

Table 2: Correlation coefficients for herbage yield, andrographolide content and their components in kalmegh.

Character		PH	PS	NOP	NOS	LAI	NOL	LDW	SDW	TDW	LA	SA	TA
PH	G	1	0.768**	0.161	0.134	-0.191	-0.249	-0.247	0.183	0.126	-0.170	0.358	0.094
	P	1	0.743**	0.128	0.116	-0.186	-0.244	-0.247	0.179	0.124	-0.172	0.346	0.08
PS	G		1	0.227	0.166	0.046	0.003	0.091	0.327	0.309	-0.062	0.431	0.216
	P		1	0.183	0.171	0.045	0.006	0.082	0.324	0.307	-0.056	0.425	0.212
NOP	G			1	1.050	0.086	0.359	0.273	0.054	0.124	0.120	-0.179	-0.021
	P			1	0.896	0.112	0.318	0.270	0.049	0.108	0.128	-0.165	-0.004
NOS	G				1	0.084	0.353	0.277	-0.015	0.056	0.118	-0.253	-0.068
	P				1	0.088	0.344	0.250	-0.017	0.059	0.096	-0.244	-0.074
LAI	G					1	0.847**	0.898**	0.062	0.290	0.887**	0.129	0.717**
	P					1	0.833**	0.856**	0.058	0.287	0.838**	0.126	0.687**
NOL	G						1	0.980**	0.27	0.50*	0.789**	0.193	0.686**
	P						1	0.950**	0.27	0.502*	0.764**	0.193	0.673**
LDW	G							1	0.359	0.586*	0.882	0.287	0.809**
	P							1	0.353	0.565*	0.879	0.278	0.809**
SDW	G								1	0.969**	0.224	0.881**	0.695**
	P								1	0.966**	0.223	0.878**	0.687**
TDW	G									1	0.437	0.844**	0.827**
	P									1	0.418	0.843**	0.808**
LA	G										1	0.129	0.798**
	P										1	0.126	0.806**
SA	G											1	0.700**
	P											1	0.688**
TA	G												1
	P												1

PH	Plant height	LDW	Leaf dry weight per plant
PS	Plant spread	SDW	Stem dry weight per plant
NOP	Number of primary branches per plant	TDW	Total dry weight per plant
NOS	Number of secondary branches per plant	LA	Leaf andrographolide yield per plant
LAI	Leaf area index	SA	Stem andrographolide yield per plant
NOL	Number of leaves at harvest per plant	TA	Total andrographolide yield per plant

* Significant at P = 0.05

** Significant at P = 0.01

As andrographolide yield per plant is the major concern, identifying the components that are having positive correlation with the traits like leaf andrographolide yield per plant and stem andrographolide yield per plant will be useful.

Genotypic correlation for leaf andrographolide yield per plant showed positive and highly significant correlation with leaf area index (0.887) and number of leaves per plant (0.789). Positive but non-significant correlation with leaf andrographolide yield per plant was estimated for number of primary branches (0.120), number of secondary branches (0.118), leaf dry weight (0.882), stem dry weight (0.224) and total dry weight (0.437). Similarly, non-significant negative correlation was obtained for plant height (-0.170) and plant spread (-0.062). Phenotypic correlation for leaf andrographolide yield per plant showed positive and highly significant association with leaf area index (0.838) and number of leaves per plant (0.764). Positive but non-significant correlation with leaf andrographolide yield per plant was obtained for number of primary branches (0.128), number of secondary branches (0.096), leaf dry weight (0.879), stem dry weight (0.223) and total dry weight (0.418). Similarly, non-significant negative correlation was obtained for plant height (-0.172) and plant spread (-0.056).

Genotypic correlation for stem andrographolide yield per plant showed highly positive and significant correlation with stem dry weight (0.881) and total dry weight (0.844). Positive but non-significant correlation with leaf andrographolide yield per plant was obtained for plant height (0.358), plant spread

(0.431), leaf area index (0.129), number of leaves at harvest (0.193), leaf dry weight (0.287) and leaf andrographolide yield per plant (0.129). Similarly, non-significant negative correlation was obtained for number of primary branches (-0.179) and number of secondary branches (-0.253). Phenotypic correlation for stem andrographolide yield per plant showed positive and highly significant correlation with stem dry weight (0.878) and total dry weight (0.843). Positive but non-significant correlation with leaf andrographolide yield per plant was observed for plant height (0.346), plant spread (0.425), leaf area index (0.126), number of leaves at harvest (0.193), leaf dry weight (0.278) and leaf andrographolide yield per plant (0.126). Similarly, non-significant negative correlation was obtained for number of primary branches (-0.165) and number of secondary branches (-0.244).

Total dry weight per plant is also an important criterion that needs to be concentrated for developing a superior line in kalmegh. Genotypic correlation for total dry weight per plant showed highly positive significant correlation with number of leaves at harvest (0.50*), leaf dry weight (0.586*) and stem dry weight per plant (0.969**). Positive but non-significant correlation with plant height (0.126), plant spread (0.309), number of primary branches per plant (0.124), number of secondary branches per plant (0.059) and leaf area index (0.290). Phenotypic correlation for total dry weight per plant showed highly positive significant correlation with number of leaves at harvest (0.502*), leaf dry weight (0.565*) and stem dry weight per plant (0.966**). Positive but non-significant correlation with plant height (0.124), plant spread (0.307), number of primary branches per plant (0.108), number of secondary branches per plant (0.059) and leaf area index (0.287).

Correlation study facilitates simultaneous improvement of two or more characters. Knowledge of relationship among yield components is essential for the formulation of breeding programmes aimed at achieving the desirable combination of various components of yield. In the present study, results revealed that leaf andrographolide yield per plant established highly positive significant association with two characters *viz.*, leaf area index and number of leaves. Stem andrographolide yield per plant established highly positive significant association with stem dry weight and total dry weight. Similar results for positive correlation in other medicinal plants were already reported by Kubsad *et al.* (2009) in ashwagandha [6], Singh *et al.* (2004) in opium [7], Chitra *et al.* (2010) in glory lily [8] and Misra *et al.* (2013) in Bishop's weed [9].

Path Co-Efficient Analysis

The direct and indirect effects of herbage yield, andrographolide content and its attributing traits were estimated by path analysis and are presented in Table 3. A residual effect of -0.0167 was observed on variability in herbage yield and andrographolide content by the characters chosen for study.

Table 3: Direct and indirect effects of different traits on herbage yield and andrographolide content in kalmegh

	PH	PS	NOP	NOS	LAI	NOL	LDW	SDW	TDW	LA	SA	TA
PH	0.0000	0.0000	-0.0001	0.0000	0.0000	-0.0002	-0.0001	-0.0003	0.0003	0.0325	-0.0067	0.0257
PS	-0.0000	-0.0001	-0.0002	0.0001	0.0000	0.0004	0.0001	0.0004	-0.0004	0.2751	0.0592	0.3342
NOP	0.0000	-0.0000	-0.0004	0.0002	0.0000	0.0005	0.0002	0.0005	-0.0005	0.4178	0.0635	0.4811
NOS	0.0000	-0.0000	-0.0003	0.0003	0.0000	0.0010	0.0004	0.0002	-0.0005	0.3347	-0.0048	0.3298
LAI	0.0000	-0.0000	-0.0001	0.0001	0.0001	0.0017	0.0006	0.0016	-0.0016	0.4928	0.3252	0.8180
NOL	-0.0000	-0.0000	-0.0001	0.0001	0.0001	0.0020	0.0007	0.0015	-0.0016	0.5200	0.2607	0.7806
LDW	-0.0000	-0.0000	-0.0001	0.0002	0.0001	0.0019	0.0007	0.0015	-0.0016	0.5725	0.2418	0.8142
SDW	-0.0000	-0.0000	-0.0001	0.0000	0.0000	0.0012	0.0004	0.0024	-0.0020	0.3923	0.3222	0.7146
TDW	-0.0000	-0.0000	-0.0001	0.0001	0.0001	0.0016	0.0005	0.0023	-0.0021	0.4892	0.3271	0.8164
LA	0.0000	-0.0000	-0.0003	0.0001	0.0001	0.0015	0.0006	0.0014	-0.0015	0.6823	0.2188	0.9009
SA	-0.0000	-0.0000	-0.0001	-0.0000	0.0000	0.0011	0.0003	0.0016	-0.0014	0.3068	0.4865	0.7934

PH	Plant height	LDW	Leaf dry weight per plant
PS	Plant spread	SDW	Stem dry weight per plant
NOP	Number of primary branches per plant	TDW	Total dry weight per plant
NOS	Number of secondary branches per plant	LA	Leaf andrographolide yield per plant
LAI	Leaf area index	SA	Stem andrographolide yield per plant
NOL	Number of leaves at harvest per plant	TA	Total andrographolide yield per plant

Out of 12 biometric characters studied, leaf andrographolide yield per plant and stem andrographolide yield per plant alone showed very high direct effect on total andrographolide yield per plant. Negligible direct effects on total andrographolide yield per plant were contributed by remaining 10 characters studied. Among them plant spread, number of primary branches and total dry weight had negligible negative direct effect on yield.

Characters like leaf dry weight, number of leaves at harvest, leaf area index, total dry weight, number of primary branches, stem dry weight and number of secondary branches had high indirect effect in the descending order on total andrographolide yield per plant *via* leaf andrographolide yield per plant. Plant spread had moderate indirect effect on total andrographolide yield per plant *via* leaf andrographolide yield per plant whereas negligible indirect effect on total andrographolide yield per plant *via* leaf andrographolide yield per plant was affected by plant height.

Total dry weight, leaf area index and stem dry weight had high indirect effect in the descending order on total andrographolide yield per plant via stem andrographolide yield per plant. Moderate indirect effect on total andrographolide yield per plant via stem andrographolide yield per plant was recorded by number of leaves at harvest, leaf dry weight and leaf andrographolide yield per plant in the descending order. Negligible indirect effect on total andrographolide yield per plant via stem andrographolide yield per plant was recorded by number of primary branches and plant spread. Negligible negative indirect effect on total andrographolide yield per plant via stem andrographolide yield per plant was recorded by plant height and number of secondary branches.

From the path analysis it is evident that leaf andrographolide yield and stem andrographolide yield per plant are directly contributing to total andrographolide yield per plant and also selection on traits such as leaf area index, number of leaves at harvest, leaf dry weight and stem dry weight per plant would be helpful in getting higher total andrographolide yield per plant in kalmegh.

Conclusion

Generally correlation measures only mutual association whereas path coefficient measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects. The study of correlation and path analysis of this experiment revealed that increase in leaf andrographolide yield per plant and stem andrographolide yield per plant together increases total andrographolide yield in kalmegh because of its high positive association and also improvement in traits like leaf area index, number of leaves at harvest, leaf dry weight and stem dry weight per plant contributes to the increased total dry weight per plant and total andrographolide yield per plant.

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