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Study of Genetic Association among Yield and Biochemical Traits in Kalmegh (*Andrographis paniculata*)

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ABSTRACT

The correlation study revealed dry herbage yield had positive and highly significant association with fresh leaf yield, dry leaf yield, fresh stem yield, dry stem yield, fresh herbage yield, canopy spread, length of primary branches, total length of primary branch, andrographolide yield in leaf, stem and herbage, neo andrographolide yield in herbage and 14-deoxy 11,12 di dehydro andrographolide yield in herbage at both genotypic and phenotypic level. Therefore, simultaneous improvement of the above said characters contributes to the improvement of dry herbage yield. Further, path coefficient analysis revealed that number of primary nodes per plant is the only parameter which had a direct positive effect on dry herbage yield, andrographolide content and yield in herbage, hence direct selection of this trait might be rewarding for the improvement of yield of kalmegh.

Keywords *Andrographis paniculata*, Correlation, Dry herbage yield.

INTRODUCTION

Among the numerous medicinal herbs, *Andrographis paniculata* (Burm. f.) Wall. ex Nees. is a very valuable medicinal plant generally known as kalmegh or kariyatu, green chirayita Creat or King of bitters. It belongs to family Acanthaceae widely found in plains of India. It grows in wild across India from southern Peninsula to Northern Plains Introduction and Eastern India. It is also found in other Asian countries and is used as a local herbal medicine in China, Hong Kong, the Philippines, Malaysia, Indonesia, Thailand and Sri Lanka. In India it is found in the states of Madhya Pradesh, Chhattisgarh, Odisha, Maharashtra, Assam, Bihar, West Bengal, Uttar Pradesh, Tamilnadu and Kerala (Pandey and Mandal 2010). The herbal formulation is traditionally used as stomachic, tonic, antipyretic, alternative and anthelmintic agents. Owing to its diversified therapeutic uses, the species is kept at 17th place among 32 prioritized medicinal plants of India with an annual demand of 2197.3 tons (Pandey and Mandal 2010).

Andrographis paniculata is having a diversified habitat, e.g. plains, hill slopes, wastelands, farms, dry or wetlands, sea shores and even road sides. The plant needs hot and humid climate with ample sunshine. It is an annual plant of over 30–110 cm height, stem acutely quadrangular with numerous branches distributed widely. Leaves are simple, lanceolate, opposite, short-petioled, 3–7 cm long and 1–2.3 cm broad in size having hairiness with slightly undulate margin,

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acuminate apex with a tapering base. Flowers are tiny, solitary found in panicles and whitish or light pink colored corolla with hairs. Capsules are erect, linear or oblong, having many yellowish-brown seeds which are subquadrate in nature. Plant is erect with bitter in taste. Plant grows luxuriantly during monsoon and flowering starts within 90–120 days in the month of September. In northern India, flowering and fruiting continues up to December until temperature falls low. Maximum plant biomass can be recorded in 110–130 days beyond which leaves shedding occurs. Harvesting should be completed at the time of flower initiation stage, when the major active principle compound, andrographolide is maximum in leaves. Since the whole herb comprises active principle, the entire harvested plant is dried in shade and powdered. A well nurtured crop grown during monsoon yields 3.5–5.0 tonnes/ha of dried herb.

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, neoandrographolide, 14-deoxyandrographolide. Andrographolide (C20H30O5) 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 (Deora 2014).

MATERIALS AND METHODS

The field experiment was carried out at ICAR Directorate of Medicinal and Aromatic Plants Research (ICAR-DMAPR), Boriavi during *kharif* 2019. The experimental material comprised of thirty diverse genotypes of kalmegh. The seeds of these genotypes were obtained from ICAR-DMAPR. The 30 genotypes were evaluated in a Randomized Block Design (RBD) with three replications. The experimental material was evaluated for different morphological, yield and chemical parameters. Morphological characters included plant height, leaf length, leaf breadth, leaf area, number of primary nodes per plant, number of primary branches per plant, number of secondary branches per primary branch, length of primary branch, total length of primary branch per plant, length of internodes, angle of primary branch and canopy spread. Yield parameters included fresh leaf and stem yields, fresh herbage yield, dry leaf and stem yields, dry herbage yield, leaf dry matter content, stem dry matter content, herbage dry matter content, fresh and dry leaf portions and fresh and dry stem portions. Chemical parameters included contents (%) of andrographolide, neo andrographolide, andrographiside and 14-deoxy-11,12 didehydro andrographolide and their yields (kg ha^{-1}) in leaf, stem and herbage.

The observations were recorded for twelve morphological, eleven yield and twenty-four biochemical characters. The genotypic correlation coefficient and phenotypic correlation coeffeicent were estimated as suggested by Hazel *et al.* (1943). The path coefficient analysis was carried-out according to the method suggested by Wright (1921) and used by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The phenotypic and genotypic correlation coefficients were estimated among 47 characters of 30 kalmegh genotypes, to find out the association of herbage yield and other yield contributing characters (Tables 1, 2). The data showed that correlation at genotypic and phenotypic levels had similar trend. Values of genotypic correlation coefficients were higher than those of their respective phenotypic correlation coefficients in most of the cases, suggesting that there was a strong and inherent association between the two characters. In some cases, however, the phenotypic correlation was slightly higher than their genotypic counterpart, which implied that the non-genetic causes inflated the value of genotypic correlation because of the influence of environmental factors.

As the dry herbage yield is of main concern in influencing the andrographolide content in kalmegh, it has positive and highly significant correlation with fresh and dry leaf yield, fresh and dry stem yield, fresh herbage yield, canopy spread, length of primary branches, total length of primary branches, andrographiside yield in leaf, andrographiside yield in stem, 14-deoxy-11,12 didehydro andrographolide

Table 1. Genotypic correlation among different characters in kalmegh. *, ** Significant at p=0.05 and p= 0.01 levels of probability, respectively. FLY- Fresh leaf yield, DLY- Dry leaf yield, FSY- Fresh stem yield, DSY-Dry stem yield, LDM -Leaf dry matter content, SDM – Stem dry matter content, FHY- Fresh herbage yield, HDC- Herbage dry matter content, FLSR-Fresh leaf : Stem ratio, DLSR- Dry leaf : Stem ratio, PH- Plant height, CANO- Canopy spread, NPB- Number of primary branches per plant, NON- Number of primary nodes per plant, LPB- Length of primary branch, NSB- Number of secondary branches, LINT- Length of internodes, ANG- Angle of primary branch, LA- Leaf area, LL- Leaf length, LB- Leaf breadth, TLPB- Total length of primary branch, X1- Andrographiside content in leaf, X2- Andrographolide content in leaf, X3- Neo andrographolide content in leaf, X4- 14-deoxy-11,12 didehydro andrographolide content in leaf, X5- Andrographiside yield in leaf, X6- Andrographolide yield in leaf, X7- Neo andrographolide yield in leaf, X8- 14-deoxy-11,12 didehydro andrographolide yield in leaf, X9- Andrographiside content in stem, X10- Andrographolide content in stem, X11- Neo andrographolide content in stem, X12-14-deoxy-11,12 didehydro andrographolide content in yield, X13- Andrographiside yield in stem, X14- Andrographolide yield in stem, X15- Neo andrographolide yield in stem X16-14-deoxy-11,12 didehydro andrographolide yield in stem, X17- Andrographiside content in herbage, X18- Andrographolide content in herbage, X19- Neo andrographolide content in herbage, X20-14-deoxy-11,12 didehydro andrographolide content in herbage, X21- Andrographiside yield in herbage, X22-Andrographolide yield in herbage, X23- Neo andrographolide yield in herbage, X24-14-deoxy-11,12 didehydro andrographolide yield in herbage.

Characters	FLY	DLY	FSY	DSY	LDM	SDM	FHY	HDC	FLP	DLP	PH	CANO
FLY	1.00											
DLY	0.97**	1.00										
FSY	0.27	0.29	1.00									
DSY	0.09	0.13	0.97**	1.00								
LDM	-0.76**	-0.58**	-0.09	0.10	1.00							
SDM	-0.60**	-0.50**	0.16	0.40*	0.76**	1.00						
FHY	0.70**	0.70**	0.88**	0.76**	-0.44*	-0.18	1.00					
HDC	-0.70**	-0.55**	0.03	0.26	0.92**	0.95**	-0.32	1.00				
FLP	0.69**	0.64**	-0.47**	-0.63**	-0.68**	-0.76**	0.00	-0.74**	1.00			
DLP	0.61**	0.60**	-0.53**	-0.69**	-0.56**	-0.77**	-0.09	-0.68**	0.98**	1.00		
PH	0.05	0.06	0.53**	0.48**	-0.07	-0.15	0.42*	-0.13	-0.27	-0.24	1.00	
CANO	-0.11	-0.03	0.56**	0.62**	0.27	0.43*	0.36*	0.37*	-0.52**	-0.53**	0.30	1.00
NPB	-0.18	-0.16	0.37*	0.44*	0.16	0.33	0.19	0.28	-0.44*	-0.44*	0.43*	0.50**
NON	-0.16	-0.13	0.33	0.39*	0.12	0.28	0.16	0.23	-0.38*	-0.38*	0.46**	0.48**
LPB	0.40*	0.40*	0.64**	0.56**	-0.38*	-0.23	0.68**	-0.32	-0.01	-0.05	0.87**	0.21
NSB	-0.16	-0.12	0.25	0.32	0.11	0.29	0.11	0.22	-0.31	-0.33	0.13	0.51**
LINT	0.01	0.02	-0.15	-0.21	-0.04	-0.33	-0.11	-0.20	0.19	0.26	0.55**	-0.28
ANG	-0.45*	-0.40*	-0.06	0.02	0.44*	0.25	-0.27	0.35	-0.37*	-0.29	0.34	0.29
LA	0.31	0.28	-0.23	-0.30	-0.26	-0.38*	-0.01	-0.32	0.43*	0.46**	0.10	-0.48**
LL	0.01	-0.02	-0.15	-0.14	-0.01	-0.06	-0.27	-0.02	0.08	0.11	0.26	-0.39*
LB	0.33	0.32	-0.30	-0.37*	-0.27	-0.39*	-0.11	-0.33	0.52**	0.55**	-0.11	-0.40*
TLB	0.20	0.21	0.59**	0.57**	-0.19	0.00	0.54**	-0.09	-0.19	-0.23	0.80**	0.46**
X1	0.22	0.19	0.35	0.24	-0.21	-0.33	0.37*	-0.31	-0.03	-0.02	0.31	-0.13
X2	0.12	0.05	-0.17	-0.21	-0.28	-0.19	-0.07	-0.25	0.22	0.18	-0.18	-0.10
X3	-0.25	-0.22	0.11	0.006	0.22	-0.14	-0.04	0.00	-0.25	-0.16	0.35	-0.07
X4	0.17	0.12	-0.15	-0.20	-0.19	-0.17	-0.02	-0.19	0.25	0.23	-0.10	-0.14
X5	0.71**	0.71**	0.38*	0.20	-0.48**	-0.56**	0.64**	-0.55**	0.37*	0.36*	0.25	-0.18
X6	0.84**	0.83**	0.12	-0.04	-0.63**	-0.53**	0.51**	-0.60**	0.67**	0.61**	0.00	-0.10
X7	0.24	0.28	0.25	0.11	-0.08	-0.40*	0.31	-0.28	0.07	0.14	0.29	-0.11
X8	0.87**	0.86**	0.20	0.03	-0.57**	-0.49**	0.58**	-0.54**	0.63**	0.58**	0.07	-0.10
X9	-0.38	-0.35	0.18	0.24	0.44*	0.31	-0.05	0.36*	-0.53**	-0.47**	0.03	0.16
X10	-0.36	-0.35	-0.15	-0.05	0.35	0.30	-0.29	0.32	-0.24	-0.20	-0.15	0.16
X11	-0.40	-0.39*	0.20	0.23	0.30	0.11	-0.05	0.17	-0.44*	-0.38*	0.50**	0.18
X12	-0.09	-0.08	-0.37*	-0.37*	0.05	-0.13	-0.32	-0.04	0.24	0.30	-0.05	-0.12
X13	-0.20	-0.16	-0.76**	0.82**	0.33	0.46**	0.46**	0.40*	-0.74**	-0.75**	0.35	0.50**
X14	-0.27	-0.23	0.38*	0.49**	0.37*	0.51**	0.15	0.45*	-0.53**	-0.54**	0.11	0.43*
X15	-0.31	-0.30	0.51**	0.54**	0.27	0.25	0.22	0.24	-0.58**	-0.57**	0.55**	0.36*
X16	0.05	0.10	0.70**	0.74**	0.16	0.35	0.54**	0.27	-0.44*	-0.47**	0.43*	0.53**
X17	0.43*	0.42*	0.12	-0.04	-0.34	-0.55**	0.30	-0.49**	0.32	0.35	0.17	-0.35
X18	0.32	0.27	-0.45*	-0.53**	-0.37*	-0.44*	-0.18	-0.42*	0.63**	0.63**	-0.28	-0.32
X19	-0.02	0.01	-0.08	-0.18	0.03	-0.40*	-0.06	-0.22	0.10	0.21	0.29	0.25
X20	0.48**	0.45*	-0.45*	-0.57**	-0.43*	-0.57**	-0.09	-0.52**	0.79**	0.80**	-0.16	-0.41*

Table 1. Continued.

Characters	FLY	DLY	FSY	DSY	LDM	SDM	FHY	HDC	FLP	DLP	PH	CANO
X21	0.60**	0.60**	0.57**	0.43*	-0.35	-0.38*	0.72**	-0.39*	0.12	0.11	0.33	-0.02
X22	0.68**	0.68**	0.30	0.20	-0.42*	-0.26	0.56**	-0.35	0.38*	0.33	0.06	0.12
X23	0.18	0.22	0.32	0.19	-0.03	-0.33	0.32	-0.23	-0.03	0.04	0.36*	-0.05
X24	0.81**	0.82**	0.42*	0.28	-0.46**	-0.33	0.71**	-0.40*	0.42*	0.37*	0.21	0.08
DHY	0.51**	0.56**	0.94**	0.89**	-0.18	0.11	0.95**	-0.03	-0.24	-0.31	0.43*	0.51**

Table 1. Continued.

Characters	NPB	NON	LPB	NSB	LINT	ANG	LA	LL	LB	TLB	X1	X2
FLY												
DLY												
FSY												
DSY												
LDM												
SDM												
FHY												
HDC												
FLP												
DLP												
PH												
CANO												
NPB	1.00											
NON	0.98**	1.00										
LPB	0.20	0.24	1.00									
NSB	0.67**	0.70**	0.18	1.00								
LINT	-0.26	-0.28	0.44*	-0.47**	1.00							
ANG	0.38*	0.31	0.08	0.11	0.33	1.00						
LA	-0.47**	-0.43*	0.17	-0.47**	0.55**	-0.07	1.00					
LL	-0.27	-0.24	0.29	-0.28	0.50**	-0.06	0.72**	1.00				
LB	-0.39*	-0.34	-0.04	-0.26	0.30	-0.13	0.80**	0.27	1.00			
TLB	0.81**	0.81**	0.74**	0.50**	0.09	0.26	-0.20	-0.09	-0.23	1.00		
X1	0.06	0.16	0.27	-0.02	-0.17	-0.18	0.11	0.01	0.13	0.19	1.00	
X2	0.07	0.22	-0.03	0.15	-0.38*	-0.27	0.00	-0.19	0.25	0.05	0.19	1.00
X3	0.09	0.12	0.03	-0.04	0.35	0.03	-0.21	-0.06	-0.28	0.12	0.16	-0.24
X4	-0.09	-0.02	-0.02	-0.18	0.10	0.07	0.33	-0.04	0.60**	-0.02	-0.07	0.46**
X5	-0.07	0.00	0.40*	-0.14	-0.05	-0.34	0.31	0.09	0.31	0.23	0.81**	0.09
X6	-0.04	0.06	0.37*	0.02	-0.13	-0.46**	0.18	-0.09	0.33	0.27	0.22	0.56**
X7	-0.01	0.03	0.17	-0.09	0.25	-0.22	-0.10	-0.13	-0.10	0.17	0.29	-0.14
X8	-0.16	-0.12	0.37*	-0.22	0.14	-0.29	0.37*	0.00	0.51**	0.30	0.11	0.21
X9	0.33	0.33	-0.31	0.23	-0.35	0.00	-0.49**	-0.14	-0.59**	0.02	0.31	-0.01
X10	0.39*	0.39*	-0.42*	0.33	-0.26	0.14	-0.41*	-0.19	-0.40*	0.01	-0.12	0.20
X11	0.32	0.24	0.11	0.06	0.33	0.24	-0.31	0.10	-0.50**	0.25	-0.09	-0.45*
X12	0.14	0.23	-0.11	0.17	0.20	0.19	-0.06	0.03	-0.08	0.05	-0.28	0.17
X13	0.49**	0.45*	0.18	0.34	-0.32	0.01	-0.50**	-0.19	-0.59**	0.39*	0.34	-0.17
X14	0.56**	0.53**	-0.11	0.41*	-0.35	0.11	-0.50**	-0.25	-0.51**	0.28	0.03	0.05
X15	0.37*	0.27	0.31	0.20	0.19	0.19	-0.41*	0.04	-0.60**	0.37*	0.00	-0.52**
X16	0.55**	0.55**	0.44*	0.41*	-0.10	0.15	-0.33	-0.12	-0.44*	0.58**	0.04	-0.11
X17	-0.09	0.02	0.17	-0.15	-0.08	-0.31	0.22	0.09	0.22	0.07	0.90**	0.19
X18	-0.05	0.08	-0.18	0.04	-0.14	-0.30	0.07	-0.11	0.27	-0.06	0.02	0.75**
X19	-0.03	0.02	0.11	-0.16	0.45*	-0.06	-0.01	0.02	-0.05	0.06	0.11	-0.17
X20	-0.26	-0.17	-0.01	-0.25	0.32	-0.10	0.42*	0.07	0.60**	-0.08	-0.15	0.33
X21	0.08	0.13	0.42*	-0.03	-0.14	-0.31	0.14	0.02	0.11	0.33	0.85**	0.04
X22	0.23	0.31	0.30	0.21	-0.30	-0.39*	-0.08	-0.21	0.07	0.39*	0.23	0.56**
X23	0.04	0.07	0.21	-0.05	0.26	-0.18	-0.16	-0.11	-0.18	0.22	0.27	-0.21
X24	0.04	0.08	0.49**	-0.06	0.10	-0.21	0.22	-0.04	0.32	0.38*	0.12	0.15
DHY	0.30	0.27	0.64**	0.21	-0.17	-0.17	-0.12	-0.13	-0.16	0.57**	0.29	-0.15

Table 1. Continued.

Characters	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
FLY												
DLY												
FSY												
DSY												
LDM												
SDM												
FHY												
HDC												
FLP												
DLP												
PH												
CANO												
NPB												
NON												
LPB												
NSB												
LINT												
ANG												
LA												
LL												
LB												
TLB												
X1												
X2												
X3	1.00											
X4	-0.06	1.00										
X5	0.02	0.03	1.00									
X6	-0.21	0.31	0.60**	1.00								
X7	0.86**	0.07	0.39*	0.23	1.00							
X8	-0.11	0.57**	0.59**	0.81**	0.34	1.00						
X9	0.38*	-0.40*	0.02	-0.27	0.22	-0.46**	1.00					
X10	0.03	-0.14	-0.31	-0.16	-0.16	-0.36*	0.69**	1.00				
X11	0.69**	-0.21	-0.27	-0.48**	0.44*	-0.32	0.43*	0.30	1.00			
X12	0.07	0.20	-0.24	0.09	0.01	0.04	0.13	0.61**	0.19	1.00		
X13	0.30	-0.37*	0.12	-0.23	0.21	-0.27	0.75**	0.38*	0.45*	-0.16	1.00	
X14	0.06	-0.22	-0.16	-0.17	-0.07	-0.30	0.74**	0.83**	0.40*	0.32	0.78**	1.00
X15	0.53**	-0.35	-0.17	-0.45*	0.34	-0.31	0.47**	0.25	0.91**	0.06	0.68**	0.53**
X16	0.11	-0.06	0.04	0.04	0.14	0.08	0.35	0.37*	0.37*	0.34	0.71**	0.72**
X17	0.15	-0.07	0.89**	0.44*	0.39*	0.30	0.28	-0.07	-0.16	-0.10	0.12	-0.07
X18	-0.18	0.32	0.14	0.66**	-0.02	0.34	0.01	0.42*	-0.32	0.56**	-0.36*	0.08
X19	0.93**	0.06	0.14	0.02	0.90**	0.12	0.19	-0.04	0.57**	0.19	0.02	-0.13
X20	-0.05	0.69**	0.18	0.58**	0.19	0.70**	-0.47**	-0.06	-0.24	0.55**	-0.65**	-0.36*
X21	0.11	-0.08	0.96**	0.49**	0.42*	0.46**	0.24	-0.18	-0.12	-0.27	0.41*	0.08
X22	-0.17	0.19	0.50**	0.88**	0.18	0.64**	0.10	0.26	-0.26	0.25	0.16	0.33
X23	0.89**	0.01	0.34	0.14	0.99**	0.27	0.28	-0.11	0.56**	0.02	0.30	0.02
X24	-0.07	0.50**	0.55**	0.75**	0.36*	0.94**	-0.30	-0.20	-0.16	0.16	0.00	-0.02
DHY	-0.04	-0.11	0.49**	0.34	0.22	0.42*	0.04	-0.20	0.02	-0.34	0.61**	0.31

Table 1. Continued.

Characters	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
FLY										
DLY										
FSY										
DSY										

Table 1. Continued.

Characters	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
LDM										
SDM										
FHY										
HDC										
FLP										
DLP										
PH										
CANO										
NPB										
NON										
LPB										
NSB										
LINT										
ANG										
LA										
LL										
LB										
TLB										
X1										
X2										
X3										
X4										
X5										
X6										
X7										
X8										
X9										
X10										
X11										
X12										
X13										
X14										
X15										
X16										
X17	1.00									
X18	0.59**	1.00								
X19	-0.14	-0.09	1.00							
X20	-0.48**	-0.14	0.29	1.00						
X21	0.33	-0.04	0.25	0.05	1.00					
X22	-0.36*	-0.44*	-0.17	0.13	0.66**	0.26	1.00			
X23	0.08	0.04	0.25	0.86**	0.03	0.13	-0.03	1.00		
X24	0.33	-0.18	0.39*	0.38*	0.67**	-0.05	0.38*	0.51**	1.00	
DHY	0.02	0.47**	0.22	0.34	-0.09	0.89**	0.11	0.40*	0.14	1.00

yield in stem, andrographiside yield in herbage, andrographolide yield in herbage and 14-deoxy-11,12 didehydro andrographolide yield in herbage at both genotypic and phenotypic level. Positive and significant correlation was observed for plant height and 14-deoxy-11,12 didehydro andrographolide yield in leaf. Similarly, positive but non-significant correlation was observed for stem dry matter content, number of primary branches, number of primary nodes per plant, number of secondary branches, andrographiside content in leaf, andrographolide yield in leaf, neo andrographolide yield in leaf, andrographiside content in stem, neo andrographolide content in stem, andrographolide yield in stem, neo andrographolide yield in stem, andrographiside content in herbage and neo andrographolide yield in herbage.

Negative and non-significant correlation was

Table 2. Phenotypic correlation among different characters in kalmegh. *, ** Significant at p=0.05 and p= 0.01 levels of probability, respectively. FLY- Fresh leaf yield, DLY- Dry leaf yield, FSY- Fresh stem yield, DSY-Dry stem yield, LDM -Leaf dry matter content, SDM – Stem dry matter content, FHY- Fresh herbage yield, HDC- Herbage dry matter content, FLP-Fresh leaf percent, DLP- Dry leaf percent, PH- Plant height, CANO- Canopy spread, NPB- Number of primary branches per plant, NON- Number of primary nodes per plant, LPB- Length of primary branch, NSB- Number of secondary branches, LINT- Length of internodes, ANG- Angle of primary branch, LA- Leaf area, LL- Leaf length, LB- Leaf breadth, TLPB- Total length of primary branch, X1- Andrographiside content in Leaf, X2- Andrographolide content in leaf, X3- Neo andrographolide content in leaf, X4- 14-deoxy-11,12 didehydro andrographolide content in leaf, X5- Andrographiside yield in leaf, X6- Andrographolide yield in leaf, X7- Neo andrographolide yield in leaf, X8- 14-deoxy-11,12 didehydro andrographolide yield in leaf, X9- Andrographiside content in stem, X10- Andrographolide content in stem, X11- Neo andrographolide content in stem, X12-14-deoxy-11,12 didehydro andrographolide content in yield, X13- Andrographiside yield in stem, X14- Andrographolide yield in stem, X15- Neo andrographolide yield in stem X16-14-deoxy-11,12 didehydro andrographolide yield in stem, X17- Andrographiside content in herbage, X18- Andrographolide content in herbage, X19- Neo andrographolide content in herbage, X20-14-deoxy-11,12 didehydro andrographolide content in herbage, X21- Andrographiside yield in herbage, X22-Andrographolide yield in herbage, X23- Neo andrographolide yield in herbage, X24-14-deoxy-11,12 didehydro andrographolide yield in herbage, DHY- Dry herbage yield.

Characters	FLY	DLY	FSY	DSY	LDM	SDM	FHY	HDC	FLSR	DLSR	PH	CANO
FLY	1.00											
DLY	0.96**	1.00										
FSY	0.41**	0.44**	1.00									
DSY	0.23*	0.28**	0.96**	1.00								
LDM	-0.61**	-0.39**	-0.08	0.07	1.00							
SDM	-0.50**	-0.43**	0.07	0.35**	0.54**	1.00						
FHY	0.76**	0.76**	0.91**	0.79**	-0.34**	-0.19	1.00					
HDC	-0.60**	-0.45**	-0.02	0.24*	0.82**	0.92**	-0.30**	1.00				
FLSR	0.62**	0.54**	-0.42**	-0.56**	-0.59**	-0.62**	-0.01	-0.66**	1.00			
DLSR	0.55**	0.53**	-0.45**	-0.61**	-0.41**	-0.69**	-0.06	-0.63**	0.96**	1.00		
PH	0.09	0.09	0.46**	0.44**	-0.09	-0.04	0.37**	-0.07	-0.24*	-0.23*	1.00	
CANO	-0.05	0.03	0.48**	0.53**	0.24*	0.30**	0.32**	0.29**	-0.47**	-0.46**	0.30**	1.00
NPB	-0.17	-0.13	0.29**	0.37**	0.19	0.30**	0.13	0.29**	-0.42**	-0.40**	0.39**	0.48**
NON	-0.15	-0.11	0.26*	0.32**	0.18	0.23*	0.12	0.24*	-0.36**	-0.34**	0.42**	0.44**
LPB	0.36**	0.37**	0.53**	0.46**	-0.23*	-0.16	0.55**	-0.22*	-0.04	-0.07	0.70**	0.27**
NSB	-0.12	-0.08	0.22*	0.27**	0.11	0.21	0.10	0.19	-0.29**	-0.30**	0.12	0.44**
LINT	0.04	0.04	-0.10	-0.15	-0.07	-0.23*	-0.05	-0.17	0.16	0.20*	0.47**	-0.20*
ANG	-0.39**	-0.34**	-0.07	-0.01	0.34**	0.18	-0.23*	0.29**	-0.33**	-0.25*	0.31**	0.24*
LA	0.28**	0.25*	-0.18	-0.24*	-0.21*	-0.28**	0.00	-0.25*	0.41**	0.42**	0.12	-0.39**
LL	0.02	0.01	-0.11	-0.11	-0.02	-0.08	-0.06	-0.05	0.07	0.09	0.23*	-0.28**
LB	0.24*	0.21*	-0.23*	-0.26*	-0.24*	-0.18	-0.05	-0.20*	0.44**	0.41**	-0.05	-0.29**
TLB	0.18	0.19	0.50**	0.49**	-0.10	0.02	0.44**	-0.03	-0.21*	-0.22*	0.68**	0.42**
X1	0.19	0.17	0.30**	0.21*	-0.18	-0.26*	0.31**	-0.27**	-0.03	-0.02	0.28**	-0.11
X2	0.11	0.04	-0.15	-0.18	-0.23*	-0.14	-0.06	-0.21*	0.21*	0.17	-0.16	-0.08
X3	-0.21*	-0.18	0.10	0.05	0.19	-0.11	-0.03	0.003	-0.24*	-0.15	0.31**	-0.06
X4	0.13	0.08	-0.13	-0.17	-0.14	-0.12	-0.04	-0.14	0.22*	0.21*	-0.11	-0.12
X5	0.73**	0.73**	0.43**	0.26*	-0.37**	-0.46**	0.65**	-0.48**	0.35**	0.36**	0.25*	-0.10
X6	0.86**	0.87**	0.28**	0.13	-0.44**	-0.44**	0.61**	-0.49**	0.58**	0.56**	0.05	-0.02
X7	0.35**	0.40**	0.35**	0.21*	-0.07	-0.35**	0.41**	-0.27**	0.08	0.15	0.27**	-0.06
X8	0.88**	0.88**	0.33**	0.17	-0.40**	-0.42**	0.65**	-0.45**	0.55**	0.54**	0.08	-0.04
X9	-0.32**	-0.29**	0.16	0.21*	0.35**	0.24*	-0.04	0.30**	-0.50**	-0.43**	0.04	0.15
X10	-0.32**	-0.29**	-0.12	-0.05	0.29**	0.23*	-0.24*	0.28**	-0.23*	-0.18	-0.14	0.14
X11	-0.35**	-0.33**	0.17	0.19	0.26*	0.07	-0.04	0.15	-0.42**	-0.35**	0.44**	0.16
X12	-0.05	-0.04	-0.27**	-0.26*	0.02	-0.06	-0.22*	-0.03	0.22*	0.25*	-0.03	-0.12
X13	-0.03	0.02	0.78**	0.85**	0.24*	0.39**	0.54**	0.34**	-0.68**	-0.69**	0.35**	0.46**
X14	-0.14	-0.09	0.45**	0.55**	0.29**	0.41**	0.26*	0.39**	-0.51**	-0.51**	0.14	0.41**
X15	-0.22*	-0.19	0.51**	0.55**	0.23*	0.22	0.26*	0.22*	-0.56**	-0.54**	0.50**	0.33**
X16	0.20*	0.26*	0.74**	0.79**	0.08	0.30**	0.63**	0.23*	-0.40**	-0.43**	0.40**	0.43**
X17	0.40**	0.38**	0.08	-0.06	-0.28**	-0.48**	0.25*	-0.46**	0.33**	0.37**	0.14	-0.31**
X18	0.30**	0.27**	-0.39**	-0.48**	-0.28**	-0.41**	-0.14	-0.40**	0.64**	0.65**	-0.27**	-0.29**
X19	0.05	0.04	-0.08	-0.18	0.03	-0.36**	-0.05	-0.22*	0.13	0.24*	0.24*	-0.23*
X20	0.43**	0.40**	-0.39**	-0.51**	-0.33**	-0.50**	-0.08	-0.47**	0.78**	0.79**	-0.17	-0.38**

Table 2. Continued.

Characters	FLY	DLY	FSY	DSY	LDM	SDM	FHY	HDC	FLSR	DLSR	PH	CANO
X21	0.65**	0.67**	0.62**	0.49**	-0.26*	-0.30**	0.75**	-0.33**	0.11	0.12	0.33**	0.04
X22	0.74**	0.77**	0.46**	0.36**	-0.28**	-0.23*	0.67**	-0.28**	0.31**	0.29**	0.11	0.16
X23	0.30**	0.34**	0.40**	0.28**	-0.03	-0.30**	0.42**	-0.22*	-0.01	0.06	0.33**	-0.01
X24	0.83**	0.86**	0.55**	0.43**	-0.32**	-0.26*	0.78**	-0.31**	0.34**	0.31**	0.21*	0.11
DHY	0.60**	0.65**	0.94**	0.91**	-0.12	0.09	0.95**	0.00	-0.21*	-0.26**	0.39**	0.43**

Table 2. Continued.

Characters	NPB	NON	LPB	NSB	LINT	ANG	LA	LL	LB	TLB	X1	X2
FLY												
DLY												
FSY												
DSY												
LDM												
SDM												
FHY												
HDC												
FLSR												
DLSR												
PH												
CANO												
NPB	1.00											
NON	0.91**	1.00										
LPB	0.24*	0.27*	1.00									
NSB	0.55**	0.60**	0.15	1.00								
LINT	-0.25*	-0.26*	0.30**	-0.39**	1.00							
ANG	0.32**	0.29**	0.06	0.07	0.32**	1.00						
LA	-0.40**	-0.37**	0.17	-0.42**	0.47**	-0.06	1.00					
LL	-0.20*	-0.21*	0.24*	-0.25*	0.42**	-0.05	0.66**	1.00				
LB	-0.28**	-0.24*	0.02	-0.22*	0.25*	-0.09	0.74**	0.26*	1.00			
TLB	0.77**	0.75**	0.71**	0.42**	0.07	0.23*	-0.15	-0.06	-0.15	1.00		
X1	0.05	0.15	0.20*	-0.02	-0.15	-0.17	0.11	0.01	0.12	0.17	1.00	
X2	0.06	0.20*	-0.03	0.14	-0.34**	-0.26*	0.004	-0.17	0.22*	0.04	0.18	1.00
X3	0.08	0.11	0.02	-0.04	0.31**	0.03	-0.20*	-0.05	-0.25*	0.10	0.16	-0.24*
X4	-0.08	-0.02	-0.04	-0.17	0.09	0.07	0.32**	-0.04	0.52**	-0.04	-0.07	0.44**
X5	-0.06	0.01	0.35**	-0.11	-0.01	-0.32**	0.30**	0.08	0.24*	0.22*	0.77**	0.09
X6	-0.04	0.05	0.34**	0.03	-0.07	-0.40**	0.17	-0.05	0.23*	0.25*	0.19	0.49**
X7	-0.01	0.03	0.19	-0.06	0.21*	-0.22*	-0.07	-0.08	-0.10	0.17	0.28**	-0.13
X8	-0.14	-0.11	0.32**	-0.17	0.13	-0.26*	0.34**	0.06	0.37**	0.18	0.10	0.18
X9	0.30**	0.30**	-0.22*	0.21*	-0.31**	0.01	-0.47**	-0.12	-0.53**	0.03	0.31**	-0.01
X10	0.34**	0.35**	-0.31**	0.31**	-0.23*	0.14	-0.40**	-0.17	-0.36**	0.004	-0.12	0.20*
X11	0.28**	0.22*	0.07	0.06	0.29**	0.22*	-0.31**	0.08	-0.46**	0.21*	-0.09	-0.45**
X12	0.12	0.18	-0.08	0.14	0.17	0.16	-0.04	0.03	-0.06	0.04	-0.26*	0.16
X13	0.43**	0.39**	0.22*	0.30**	-0.25*	-0.006	-0.42**	-0.16	-0.46**	0.37**	0.31**	-0.15
X14	0.48**	0.46**	-0.006	0.37**	-0.29**	0.09	-0.46**	-0.22*	-0.43**	0.27**	0.03	0.05
X15	0.32**	0.24*	0.25*	0.19	0.16	0.17	-0.39**	0.03	-0.52**	0.33**	-0.003	-0.50**
X16	0.43**	0.43**	0.37**	0.32**	-0.05	0.09	-0.25*	-0.09	-0.31**	0.49**	0.03	-0.08
X17	-0.10	0.02	0.12	-0.14	-0.07	-0.29**	0.21*	0.08	0.17	0.05	0.89**	0.19
X18	-0.07	0.05	-0.15	0.03	-0.12	-0.27**	0.06	-0.10	0.21*	-0.07	0.02	0.73**
X19	-0.04	0.01	0.0005	-0.15	0.40**	-0.05	-0.01	0.02	-0.06	0.04	0.11	-0.16
X20	-0.25*	-0.17	-0.05	-0.24*	0.27**	-0.08	0.40**	0.05	0.48**	-0.10	-0.15	0.32**
X21	0.07	0.12	0.38**	-0.01	-0.09	-0.29**	0.14	0.03	0.08	0.31**	0.78**	0.03
X22	0.18	0.24*	0.31**	0.18	-0.19	-0.33**	-0.04	-0.15	0.03	0.35**	0.19	0.48**
X23	0.04	0.06	0.22*	-0.03	0.22*	-0.18	-0.13	-0.07	-0.17	0.21*	0.26*	-0.19
X24	0.03	0.06	0.41**	-0.04	0.10	-0.19	0.20*	-0.03	0.22*	0.32**	0.10	0.13
DHY	0.24*	0.21*	0.52**	0.18	-0.10	-0.15	-0.08	-0.09	-0.12	0.47**	0.24*	-0.12

Table 2. Continued.

Characters	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
FLY												
DLY												
FSY												
DSY												
LDM												
SDM												
FHY												
HDC												
FLSR												
DLSR												
PH												
CANO												
NPB												
NON												
LPB												
NSB												
LINT												
ANG												
LA												
LL												
LB												
TLB												
X1												
X2												
X3	1.00											
X4	-0.06	1.00										
X5	0.02	0.01	1.00									
X6	-0.18	0.24*	0.65**	1.00								
X7	0.81**	0.05	0.45**	0.34**	1.00							
X8	-0.10	0.50**	0.63**	0.84**	0.42**	1.00						
X9	0.38**	-0.39**	0.03	-0.23*	0.20*	-0.40**	1.00					
X10	0.03	-0.13	-0.29**	-0.14	-0.15	-0.33**	0.69**	1.00				
X11	0.69**	-0.20*	-0.25*	-0.42**	0.41**	-0.28**	0.43**	0.30**	1.00			
X12	0.07	0.18	-0.19	0.10	0.03	0.05	0.13	0.58**	0.18	1.00		
X13	0.27**	-0.33**	0.18	-0.06	0.27**	-0.11	0.68**	0.35**	0.40**	-0.11	1.00	
X14	0.06	-0.21*	-0.09	-0.06	-0.003	-0.17	0.69**	0.79**	0.37**	0.30**	0.79**	1.00
X15	0.52**	-0.33**	-0.13	-0.34**	0.34**	-0.23*	0.46**	0.25*	0.88**	0.06	0.68**	0.55**
X16	0.09	-0.05	0.13	0.19	0.23*	0.21*	0.29**	0.31**	0.30**	0.36**	0.75**	0.73**
X17	0.15	-0.07	0.85**	0.40**	0.38**	0.29**	0.27**	-0.07	-0.15	-0.09	0.08	-0.08
X18	-0.17	0.30**	0.15	0.60**	0.005	0.33**	0.01	0.41**	-0.31**	0.52**	-0.35**	0.05
X19	0.91**	0.05	0.14	0.03	0.85**	0.13	0.18	-0.04	0.56**	0.17	-0.01	-0.14
X20	-0.05	0.68**	0.18	0.51**	0.19	0.64**	-0.45**	-0.06	-0.23*	0.53**	-0.61**	-0.35**
X21	0.09	-0.09	0.96**	0.57**	0.49**	0.54**	0.23*	-0.16	-0.11	-0.21*	0.46**	0.15
X22	-0.15	0.14	0.56**	0.90**	0.31**	0.70**	0.09	0.22*	-0.22*	0.23*	0.29**	0.38**
X23	0.84**	0.01	0.40**	0.26*	0.99**	0.36**	0.26*	-0.10	0.51**	0.04	0.35**	0.08
X24	-0.05	0.42**	0.60**	0.79**	0.45**	0.94**	-0.24*	-0.17	-0.14	0.17	0.17	0.10
DHY	-0.03	-0.10	0.52**	0.48**	0.33**	0.52**	0.04	-0.16	0.01	-0.22*	0.68**	0.40**

Table 2. Continued.

Characters	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
FLY										
DLY										
FSY										

Table 2. Continued.

Characters	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
DSY										
LDM										
SDM										
FHY										
HDC										
FLSR										
DLSR										
PH										
CANO										
NPB										
NON										
LPB										
NSB										
LINT										
ANG										
LA										
LL										
LB										
TLB										
X1										
X2										
X3										
X4										
X5										
X6										
X7										
X8										
X9										
X10										
X11										
X12										
X13										
X14										
X15	1.00									
X16	0.57**	1.00								
X17	-0.15	-0.11	1.00							
X18	-0.47**	-0.15	0.31	1.00						
X19	0.31**	-0.06	0.26*	0.08	1.00					
X20	-0.43**	-0.16	0.15	0.66**	0.28**	1.00				
X21	0.08	0.34**	0.79**	0.03	0.12	-0.02	1.00			
X22	-0.08	0.49**	0.34**	0.57**	-0.02	0.32**	0.59**	1.00		
X23	0.47**	0.30**	0.33**	-0.06	0.84**	0.11	0.47**	0.28**	1.00	
X24	-0.0009	0.53**	0.21*	0.23*	0.09	0.50**	0.59**	0.78**	0.42**	1.00
DHY	0.35**	0.74**	0.11	-0.27**	-0.12	-0.23*	0.67**	0.62**	0.37**	0.71**

obtained for leaf dry matter content, herbage dry matter content, fresh and dry leaf stem ratio, length of internodes, angle of primary branch, leaf area, leaf length, leaf breadth, andrographolide content in leaf, neo andrographolide content in leaf, 14-deoxy-11,12 didehydro andrographolide content in leaf, andrographolide content in stem, 14-deoxy-11,12 didehydro andrographolide content in stem, andrographolide content in herbage, neo andrographolide content in herbage and 14-deoxy-11,12 didehydro andrographolide content in herbage.

Similar findings are also observed by Pathaka (2011), Devi (2016), Pratibha (2017) and Dayana *et al.* (2018).

CONCLUSION

The correlation study revealed dry herbage yield had

positive and highly significant association with fresh leaf yield, dry leaf yield, fresh stem yield, dry stem yield, fresh herbage yield, canopy spread, length of primary branches, total length of primary branch, andrographolide yield in leaf, stem and herbage, neo andrographolide yield in herbage and 14-deoxy-11,12 di dehydro andrographolide yield in herbage at both genotypic and phenotypic level. Therefore, simultaneous improvement of the above said characters contributes to the improvement of dry herbage yield.

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