RESEARCH ARTICLE

CORRELATION AND PATH ANALYSIS IN ASHWAGANDHA (*WITHANIA SOMNIFERA* L.) FOR DRY ROOT YIELD

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Abstract: The experiment was laid out in a completely Randomized Block Design with 29 ashwagandha accessions as treatments during *Kharif*, 2018 at Medicinal and Aromatic Plant Research Station, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad. Each treatment was randomly replicated thrice. The results on genotypic and phenotypic correlation reveal that mostly genotypic correlation coefficient is comparatively higher than the intensity of phenotypic correlation coefficient. This indicates less influence of environment in association studies. The positive and significant correlation was observed between dry root yield per plant with root diameter, main root length, leaf length, starch estimation, leaf width, fresh leaf weight, dry leaf weight, days to flower initiation, plant height and number of secondary roots per plant. Direct selection based on these traits would result in simultaneous improvement of aforesaid traits and dry root yield per se in ashwagandha. Although correlation coefficients indicate the nature of association among the characters, path analysis splits the correlation coefficients into measures of direct and indirect effects, thus providing an understanding on the direct and indirect contribution of each character towards yield. From the foregoing discussion, it can be concluded that main root length, root diameter, leaf weight and days to flower initiation had positive correlation and positive direct effect on dry root yield per plant. These are identified as superior yield components. Hence, the genotypes which exhibited better performance for these characters can be used in further improvement of ashwagandha.

Keywords: Ashwagandha, Phenotypic correlation, Genotypic correlation, Path analysis, Dry root yield per plant

INTRODUCTION

Ashwagandha (*Withania somnifera* L.) belongs to the family Solanaceae with chromosome number 2n = 48. Ashwagandha is one of the most popular medicinal crops being commercially cultivated as a dry land crop in late *Kharif* season in India. It is commonly known as Indian Winter Cherry, Asgandh and Indian Ginseng. The origin of ashwagandha is North-Western and Central India as well as Mediterranean region of North Africa (Srivastava *et al*., 2017). The plant is an evergreen erect under shrub which is 30-150 cm tall and it produces flowers indeterminately round the year with a peak of flowering between March and July (Mir *et al*., 2012). High pollen load on the stigma and stiff pollen competition within a flower strongly favors self-pollination (Mir *et al*., 2012).

The economic part of ashwagandha is root which is rich in alkaloids, steroidal lactones and saponins. The medicinal properties of the root are attributed to the chemical quality, i.e., alkaloids (isopelletierine, anaferine), steroidal lactones (withanolides, withaferins) and saponins containing an additional acyle group (Sitoindoside VII and VIII) content (Gupta and Rana, 2007). The total alkaloid content in the Indian roots range between 0.13% and 0.31%. Withaferin A and Withanolide D are the two main withanolides which contribute to most of the biological activity of ashwagandha (Matsuda *et al*., 2001). The commercial value of roots depends upon the physical (textural) quality and root morphology. Brittle, robust and lengthy roots have high market value (Misra *et al*., 1998).

Ashwagandha roots have a tremendous medicinal value and constituent of various formulations in the traditional Indian medical systems such as Ayurveda, Unani and Siddha. (Sharma *et al*., 2014). It has anti-stress (Bhattacharya and Muruganandam, 2003), immunomodulatory, cytotoxic, anti-bacterial, antifungal, and immunosuppressive properties (Atta-ur-Rahman *et al*., 1998), treatment of rheumatic pain, inflammation of joints, female disorders, hiccups, coughs and colds, ulcers, leprosy, as a sedative *etc*, (Al-Hindwani *et al*., 1992). The bruised leaves of this plant are used in the treatment of tumors, tubercular glands and as an anti-inflammatory agent (Jayaprakasam *et al*., 2003; Chopra, 1994) due to its antibacterial, antifungal, and antitumor properties (Devi *et al*., 1993).

One of the important factors restricting the large-scale production and development of better varieties is the availability of meagre information about the genetic diversity, inter and intra-specific variability and genetic relationship among ashwagandha genotypes. Evaluation of germplasm has an immense importance in genetic improvement of the crop for achieving higher yields and productivity. Assessment of variability is most important as well as first step of any breeding programme. Greater the variability in the genetic material better are the chances of genetic improvement, provided the heritability is high and expected genetic gain under selection is more for the characters under study.

Variability studies alone will not be of much help for improvement of yield, yield attributes and quality characters. Therefore, knowledge of genetic correlation between the yield and its component

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characters is necessary for better selection programme for improvement in yield through indirect selection of component traits. However, the correlation between the yield and its component characters are not often real because of interrelationship existing between the component characters themselves. Therefore, analysis of inter component correlation is very essential to expose the direct and indirect contribution of each component which is determined by path-coefficient analysis (Wright, 1921).

MATERIALS AND METHODS

The experiment was laid out in a completely Randomized Block Design with 29 ashwagandha accessions as treatments during *Kharif*, 2018 at Medicinal and Aromatic Plant Research Station, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad. Each treatment was randomly replicated thrice.

The experimental material comprised of 29 germplasm lines of ashwagandha were obtained from DMAPR, Anand, Gujarat; CIMAP, Lucknow, Uttar Pradesh and PDKV, Akola, Maharashtra (Table 1). The recommended agronomical practices were adopted to raise a healthy crop. The experimental material was evaluated for 25 characters *viz*., Plant height (cm), number of branches per plant, leaf length (cm), leaf width (cm), days to flower initiation, days to fruit formation, days to root harvest, fresh leaf weight per plant (g), dry leaf weight per plant (g), number of berries per plant, berry diameter (cm), number of seeds per berry, seed yield per plant (g), seed yield (q ha^{-1}), main root length (cm), diameter of root (cm), number of secondary roots per plant, fresh root weight per plant (g), dry root weight per plant (g), fresh root yield (q ha^{-1}), dry root yield(q ha^{-1}), crude fiber estimation (%), starch estimation (%), starch and fiber ratio, total alkaloid content (%). Analysis of variance was calculated with the method suggested by Panse and Sukhatme, 1978. The phenotypic, genotypic and environmental correlation coefficients for all the characters were worked out. For this purpose, data were subjected to covariance analysis. Correlation and path coefficient were estimated according to Miller *et. al*.(1958) and Dewey and Lu (1959).

RESULTS AND DISCUSSION

The phenotypic (P) and genotypic (G) correlation coefficients were worked out for 21 characters in ashwagandha and the data is presented in Table 2. for *Kharif*, 2018. In general, it was observed that genotypic correlation coefficients were higher than that of phenotypic correlation coefficients. This could be interpreted on the basis that there was a strong inherent genotypic relationship between the characters studied, but their phenotypic expression was impeded by the influence of environmental factors.

The results on genotypic and phenotypic correlation reveal that mostly genotypic correlation coefficient is comparatively higher than the intensity of phenotypic correlation coefficient. This indicates less influence of environment in association studies. The trend of association observed in this study is mostly based upon the genetic contribution. Therefore, the value of 'r' for genotypic correlation between yield, yield contributing characters and quality characters should be considered for selecting the suitable characters for improvement. Similar to these results Chaudhary *et al*. (2016) and Sundesha *et al*. (2016) also observed high magnitude of genotypic correlation than the corresponding phenotypic correlation for most of the characters combinations establishing predominant role of heritable factor.

The positive and significant correlation was observed between dry root yield per plant with root diameter, main root length, leaf length, starch estimation, leaf width, fresh leaf weight, dry leaf weight, days to flower initiation, plant height and number of secondary roots per plant. Direct selection based on these traits would result in simultaneous improvement of aforesaid traits and dry root yield per se in ashwagandha.

Considering the interrelationship of various component characters with fresh root yield and among themselves, it would be possible to develop an ideal plant type of ashwagandha. Such plant should be tall statured, maximum fresh and dry leaf weight, delay flower initiation, longer root length and root diameter, and high starch content.

Although correlation coefficients indicate the nature of association among the characters, path analysis splits the correlation coefficients into measures of direct and indirect effects, thus providing an understanding on the direct and indirect contribution of each character towards yield.

Path analysis was carried out at phenotypic and genotypic level considering dry root yield per plant (g) as dependent variable and its attributes as independent variables. Each component has two path actions *viz*., direct effect on yield and indirect effect through components which are not revealed by correlation studies. The estimates of direct and indirect effects of the twenty yield related characters on dry root yield per plant are presented in table 3 for *Kharif*, 2018

If both correlation coefficient and the direct effect are high and positive then correlation explains its true relationship and a selection for that character will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, in such relations the indirect causal factors are to be considered simultaneously for selection, when correlation coefficient is negative but the direct effect is positive and high in such cases direct selection for such traits should be practiced to reduce the undesirable indirect effect.

Similar results were reported in chilli by Sundesha *et al*. (2016), Joshi *et al*. (2014), Sangwan *et al*. (2013) and Kumar *et al*. (2011c).

The residual factor determines how best the causal factors account for the variability of the dependent factor, the dry root yield per plant in this case. The residual effects were 0.261 and 0.200, which were of low magnitude at genotypic and phenotypic levels in *Kharif*, 2018.

From the foregoing discussion, it can be concluded that main root length, root diameter, leaf weight and days to flower initiation had positive correlation and positive direct effect on dry root yield per plant. These are identified as superior yield components. Hence, the genotypes which exhibited better performance for these characters can be used in further improvement of ashwagandha.

Table 1. List of genotypes used for evaluation along with their sources

S. No	Accession. No	Genotype	Source
1	A_1	AKAS-13	PDKV, Akola
2	A_2	AKAS-11	PDKV, Akola
3	A_3	AKAS-10	PDKV, Akola
4	A_4	AKAS-02	PDKV, Akola
5	A_5	MWS-324	DMAPR, Gujarat
6	A_6	MWS-100	DMAPR, Gujarat
7	A_7	MWS-132	DMAPR, Gujarat
8	A_8	MWS-323	DMAPR, Gujarat
9	A_9	MWS-218	DMAPR, Gujarat
10	A_{10}	RAS-7	DMAPR, Gujarat
11	A_{11}	RAS-28	DMAPR, Gujarat
12	A_{12}	RAS-57	DMAPR, Gujarat
13	A_{13}	RAS-65	DMAPR, Gujarat
14	A_{14}	RAS-67	DMAPR, Gujarat
15	A_{15}	IC-310620(A)	DMAPR, Gujarat
16	A_{16}	IC-310620(B)	DMAPR, Gujarat
17	A_{17}	IC-283662	DMAPR, Gujarat
18	A_{18}	IC-286632	DMAPR, Gujarat
19	A_{19}	IC-283966	DMAPR, Gujarat
20	A_{20}	IC-283942	DMAPR, Gujarat
21	A_{21}	IC-310595	DMAPR, Gujarat
22	A_{22}	Red berry	DMAPR, Gujarat
23	A_{23}	BHM-42	DMAPR, Gujarat
24	A_{24}	JA-134	DMAPR, Gujarat
25	A_{25}	NMITLI-118	CIMAP, Lucknow
26	A_{26}	NMITLI-101	CIMAP, Lucknow
27	A_{27}	CIM-Chetak	CIMAP, Lucknow
28	A_{28}	CIM-Pratap	CIMAP, Lucknow
29	A_{29}	Poshita	CIMAP, Lucknow

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 29 genotypes of ashwagandha *Kharif*, 2018

Character		PH	NBRP	LL	LW	DFLI	DFF	DRH	FLWP	DLWP	NBEP	BD	NSPB	SYP	MRL
PH	P	**1.0000**	0.3993***	0.6047***	0.5503***	0.4064***	0.5241***	0.1167	0.6818***	0.7180***	0.0946	0.3762***	0.3253**	.0676	0.5997***
	G	**1.0000**	0.5681	0.8897	0.7876	0.5046	-0.6116	0.4767	0.7160	0.7744	-0.2379	0.2277	0.1437	-0.0410	0.6138
NBRP	P		**1.0000**	0.3011**	0.1819	0.1426	-0.1685	0.1657	0.5944***	0.2267***	0.2533*	0.2492*	0.0932	0.2612*	0.3381**
	G		**1.0000**	0.2635	0.0318	0.1967	-0.3045	0.3577	0.8141	0.7283	0.2838	0.4564	0.1767	0.3695	0.3888
LL	P			**1.0000**	0.8684***	0.5708***	0.3904***	0.2103	0.5356***	0.6067***	0.2960**	0.0302	0.0903	-0.1220	0.4865***
	G			**1.0000**	0.9763	0.7457	-0.4950	0.6290	0.6632	0.7691	-0.4264	0.1920	0.2802	-0.1235	0.6622
LW	P				**1.0000**	0.5906***	0.3760***	0.2277*	0.3990***	0.4844***	-0.2865**	-0.0209	0.0881	-0.1819	0.4759***
	G				**1.0000**	0.7717	-0.4970	0.6298	0.4725	0.5865	-0.4436	0.0483	0.2190	-0.2198	0.6035

DFLI	**P**					**1.0000**	-0.2736*	0.7067***	0.4049***	0.4297***	-0.4528***	0.0453	0.2820**	-0.2221*	0.4555***
	G					**1.0000**	-0.4387	0.9902	0.4220	0.4546	-0.4846	0.0713	0.4149	-0.2277	0.5079
DFF	**P**						**1.0000**	0.1561	-0.3145**	-0.3445**	0.0102	-0.3897***	-0.3790***	-0.2072	-0.2770**
	G						**1.0000**	-0.6121	-0.3748	-0.4299	0.0327	-0.5879	-0.5213	-0.2338	-0.3881
DRH	**P**							**1.0000**	0.2160*	0.2271*	-0.2027	0.0881	0.1918	-0.0700	0.2688*
	G							**1.0000**	0.4042	0.4119	-0.3227	0.2808	0.6485	-0.0608	0.4821
FLWP	**P**								**1.0000**	0.9523***	0.0040	0.3195**	0.1132	0.1491	0.5462***
	G								**1.0000**	0.9754	-0.0615	0.3254	0.0374	0.1193	0.5311
DLWP	**P**									**1.0000**	0.0202	0.3664***	0.1983	0.1492	0.5809***
	G									**1.0000**	-0.0865	0.3470	0.0965	0.1052	0.5483
NBEP	**P**										**1.0000**	0.1223	-0.0030	0.8335***	-0.0946
	G										**1.0000**	-0.0278	-0.2321	0.8478	-0.2721
BD	**P**											**1.0000**	0.8001***	0.3318**	0.2795**
	G											**1.0000**	0.6645	0.2072	0.1381
NSPB	**P**												**1.0000**	0.2643*	0.2697*
	G												**1.0000**	0.1065	0.1244
SYP	**P**													**1.0000**	-0.0178
	G													**1.0000**	-0.1206
MRL	**P**														**1.0000**
	G														**1.0000**

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 29 genotypes of ashwagandha in *Kharif*, 2018 (Contd...)

Character		RD	NSRPP	CFE	SE	SFR	TA	DRWP
PH	**P**	0.6539***	0.6359***	0.7087***	0.4517***	-0.2022	-0.0269	0.6101
	G	0.7064	0.6487	0.7880	0.4608	-0.2223	-0.0773	0.6669
NBRP	**P**	0.4898***	0.5224***	0.4335***	0.3014**	-0.1102	0.0636	0.3870
	G	0.6667	0.6860	0.5417	0.3650	-0.1086	0.0295	0.5214
LL	**P**	0.5093***	0.5074***	0.6167***	0.4952***	-0.0550	0.1809	0.6517
	G	0.6587	0.6892	0.8506	0.6520	-0.0472	0.3677	0.8396
LW	**P**	0.4422***	0.4741***	0.5843***	0.4043***	-0.1208	0.1986	0.5939
	G	0.5467	0.5931	0.7847	0.5178	-0.1494	0.2738	0.7510
DFLI	**P**	0.5338***	0.5259***	0.6497***	0.4635***	-0.1348	0.0855	0.6638
	G	0.5641	0.6120	0.7400	0.5094	-0.1389	0.1136	0.6803
DFF	**P**	-0.6225***	-0.4845***	-0.5435***	-0.4850***	-0.0361	-0.1719	-0.5015
	G	-0.7983	-0.6203	-0.7813	-0.6528	-0.0413	-0.2351	-0.6412
DRH	**P**	0.3375**	0.3123***	0.3786***	0.2699*	-0.0780	0.0370	0.3526
	G	0.5866	0.6912	0.6733	0.4820	-0.1276	0.1329	0.5678
FLWP	**P**	0.6592***	0.7465***	0.5912***	0.4837***	-0.0321	0.0284	0.7180
	G	0.6553	0.7705	0.5918	0.4669	-0.0273	0.0097	0.7168
DLWP	**P**	0.7032***	0.7552***	0.6855***	0.5529***	-0.0444	0.0812	0.7421
	G	0.6820	0.7519	0.6679	0.5053	-0.0550	0.0164	0.7440
NBEP	**P**	-0.1420	0.1888	-0.0882	-0.1019	-0.0379	0.0739	-0.1978
	G	-0.2649	0.0482	-0.2856	-0.2680	-0.0476	0.0173	-0.2755
BD	**P**	0.5175***	0.3918***	0.3680***	0.4833***	0.2348*	0.0421	0.2404
	G	0.5488	0.2810	0.2697	0.4733	0.3272	-0.0077	0.2240
NSPB	**P**	0.5092***	0.3485***	0.4093***	0.4812***	0.1753	0.1440	0.2469
	G	0.5291	0.2040	0.3293	0.4518	0.2246	0.1173	0.2394
SYP	**P**	0.0423	0.3562***	0.0405	0.0951	0.0781	0.2262*	-0.0163
	G	-0.0155	0.3124	-0.0562	0.0247	0.0858	0.2644	-0.0534
MRL	**P**	0.5810***	0.5702***	0.6985***	0.6038***	-0.0044	0.1048	0.6970
	G	0.5551	0.4570	0.6250	0.5555	0.0365	0.0638	0.7044

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 29 genotypes of ashwagandha in *Kharif*, 2018 (Contd...)

Character		RD	NSRPP	CFE	SE	SFR	TA	DRWP
RD	**P**	**1.0000**	0.6596***	0.7915***	0.7553***	0.1105	0.2051	0.8137
	G	**1.0000**	0.6381	0.7994	0.7305	0.0934	0.2001	0.8209
NSRPP	**P**		**1.0000**	0.7277***	0.5332***	-0.1147	0.1623	0.6564
	G		**1.0000**	0.6629	0.4516	-0.1161	0.1441	0.6657

CFE	**P**			**1.0000**	0.6929***	-0.2167*	0.1725	0.8017
	G			**1.0000**	0.6371	-0.2318	0.1491	0.8357
SE	**P**				**1.0000**	0.5485***	0.3900***	0.7985
	G				**1.0000**	0.6015	0.4426	0.8217
SFR	**P**					**1.0000**	0.3342**	0.1471
	G					**1.0000**	0.4134	0.1650
TA	**P**						**1.0000**	0.3360
	G						**1.0000**	0.3994
DRWP	**P**							**1.0000**
	G							**1.0000**

*, **and *** Significant at P= 0.05, 0.01 and .001 levels, respectively

PH - Plant height (cm); NBRP - Number of branches per plant; LL - Leaf length (cm); LW - Leaf width (cm); DFLI - Days to flower initiation; DFF - Days to fruit formation; DRH - Days to root harvest; FLWP - Fresh leaf weight per plant (g); DLWP - Dry leaf weight per plant (g); NBEP - Number of berries per plant; BD - Berry diameter (cm); NSPB - Number of seeds per berry; SYP - Seed yield per plant (g); SYH - Seed yield (q ha^{-1}); MRL - Main root length (cm); RD - Diameter of root (cm); NSRPP - Number of secondary roots per plant;DRWP - Dry root weight per plant (g);CFE - Crude fiber estimation; SE - Starch estimation; SFR - Starch and fiber ratio; TA - Total alkaloid.

Table 3. Direct and indirect effects of various yield and yield attributes on root yield in 29 genotypes of ashwagandha in *Kharif*, 2018

Character		PH	NBRP	LL	LW	DFLI	DFF	DRH	FLWP	DLWP	NBEP	BD	NSPB	SYP	MRL
PH	**P**	**-0.0352**	-0.0141	-0.0213	-0.0194	-0.0143	0.0185	-0.0041	-0.0240	-0.0253	0.0033	-0.0133	-0.0115	-0.0024	-0.0211
	G	**-0.1289**	-0.0732	-0.1147	-0.1015	-0.0651	0.0789	-0.0615	-0.0923	-0.0998	0.0307	-0.0294	-0.0185	0.0053	-0.0791
NBRP	**P**	-0.0385	**-0.0964**	-0.0290	-0.0175	-0.0138	0.0163	-0.0160	-0.0573	-0.0537	-0.0244	-0.0240	-0.0090	-0.0252	-0.0326
	G	0.1008	**0.1775**	0.0468	0.0056	0.0349	-0.054	0.0635	0.1445	0.1293	0.0504	0.081	0.0314	0.0656	0.069
LL	**P**	-0.0427	-0.0212	**-0.0706**	-0.0613	-0.0403	0.0275	-0.0148	-0.0378	-0.0428	0.0209	-0.0021	-0.0064	0.0086	-0.0343
	G	0.4119	0.122	**0.4629**	0.452	0.3452	-0.2291	0.2912	0.3070	0.3561	-0.1974	0.0889	0.1297	-0.0572	0.3065
LW	**P**	0.0530	0.0175	0.0836	**0.0963**	0.0569	-0.0362	0.0219	0.0384	0.0466	-0.0276	-0.0020	0.0085	-0.0175	0.0458
	G	-0.7958	-0.0321	-0.9865	**-1.0104**	-0.7797	0.5021	-0.6364	-0.4774	-0.5926	0.4482	-0.0488	-0.2213	0.2221	-0.6098
DFLI	**P**	0.1256	0.0441	0.1764	0.1825	**0.3091**	-0.0846	0.2184	0.1251	0.1328	-0.1399	0.0140	0.0872	-0.0686	0.1408
	G	0.6779	0.2643	1.0017	1.0366	**1.3433**	-0.5893	1.3301	0.5669	0.6107	-0.6509	0.0958	0.5573	-0.3059	0.6823
DFF	**P**	0.0012	0.0004	0.0009	0.0009	0.0006	**-0.0023**	-0.0004	0.0007	0.0008	0.0000	0.0009	0.0009	0.0005	0.0006
	G	0.1811	0.0902	0.1466	0.1472	0.1299	**-0.2961**	0.1812	0.1110	0.1273	-0.0097	0.1741	0.1544	0.0692	0.1149
DRH	**P**	-0.0125	-0.0177	-0.0225	-0.0244	-0.0756	-0.0167	**-0.1070**	-0.0231	-0.0243	0.0217	-0.0094	-0.0205	0.0075	-0.0288
	G	-0.1259	-0.0945	-0.1661	-0.1663	-0.2615	0.1616	**-0.2641**	-0.1067	-0.1088	0.0852	-0.0742	-0.1713	0.016	-0.1273
FLWP	**P**	0.3538	0.3084	0.2779	0.2070	0.2101	-0.1632	0.1121	**0.5188**	0.4941	0.0021	0.1658	0.0587	0.0773	0.2834
	G	-0.6509	-0.7401	-0.6029	-0.4296	-0.3837	0.3407	-0.3674	**-0.9091**	-0.8867	0.056	-0.2958	-0.034	-0.1085	-0.4828
… DLWP	**P**	-0.1326	-0.1028	-0.1120	-0.0894	-0.0793	0.0636	-0.0419	-0.1758	**-0.1846**	-0.0037	-0.0677	-0.0366	-0.0276	-0.1073
	G	1.0903	1.0255	1.0829	0.8258	0.6401	-0.6053	0.58	1.3733	**1.4079**	-0.1218	0.4886	0.1359	0.1481	0.772
NBEP	**P**	-0.0053	0.0142	-0.0166	-0.0161	-0.0255	0.0006	-0.0114	0.0002	0.0011	**0.0562**	0.0069	-0.0002	0.0469	-0.0053
	G	-0.15	0.1789	-0.2689	-0.2797	-0.3056	0.0206	-0.2035	-0.0388	-0.0545	**0.6306**	-0.0175	-0.1463	0.5346	-0.1716
BD	**P**	-0.0167	-0.0111	-0.0013	0.0009	-0.0020	0.0173	-0.0039	-0.0142	-0.0163	-0.0054	**-0.0444**	-0.0356	-0.0147	-0.0124
	G	-0.0656	-0.1315	-0.0553	-0.0139	-0.0205	0.1694	-0.0809	-0.0938	-0.1	0.008	**-0.2882**	-0.1915	-0.0597	-0.0398
NSPB	**P**	-0.0500	-0.0143	-0.0139	-0.0135	-0.0433	0.0582	-0.0295	-0.0174	-0.0305	0.0005	-0.1230	**-0.1537**	-0.0406	-0.0414
	G	0.0052	0.0064	0.0101	0.0079	0.015	-0.0189	0.0235	0.0014	0.0035	-0.0084	0.0241	**0.0362**	0.0039	0.0045

SYP	**P**	0.0019	0.0074	-0.0034	-0.0051	-0.0063	-0.0058	-0.0020	0.0042	0.0042	0.0235	0.0093	0.0074	**0.0282**	-0.0005
	G	0.0212	-0.191	0.0638	0.1136	0.1177	0.1208	0.0314	-0.0617	-0.0544	-0.4383	-0.1071	-0.0551	**-0.5169**	0.0623
MRL	**P**	0.0700	0.0395	0.0568	0.0555	0.0531	-0.0323	0.0314	0.0637	0.0678	-0.0110	0.0326	0.0315	-0.0021	**0.1167**
	G	0.3336	0.2113	0.3599	0.328	0.276	-0.2109	0.262	0.2886	0.298	-0.1479	0.075	0.0676	-0.0655	**0.5435**

Table 3. Direct and indirect effects of various yield and yield attributes on root yield in 29 genotypes of ashwagandha in *Kharif*, 2018

Character		PH	NBRP	LL	LW	DFLI	DFF	DRH	FLWP	DLWP	NBEP	BD	NSPB	SYP	MRL
RD	**P**	0.2003	0.1500	0.1560	0.1354	0.1635	-0.1907	0.1034	0.2019	0.2154	-0.0435	0.1585	0.1560	0.0130	0.1779
	G	0.1602	0.1512	0.1494	0.124	0.1279	-0.181	0.133	0.1486	0.1546	-0.0601	0.1244	0.12	-0.0035	0.1259
NSRPP	**P**	-0.1191	-0.0979	-0.0950	-0.0888	-0.0985	0.0907	-0.0585	-0.1398	-0.1415	-0.0354	-0.0734	-0.0653	-0.0667	-0.1068
	G	-0.1667	-0.1763	-0.1771	-0.1524	-0.1573	0.1594	-0.1776	-0.198	-0.1933	-0.0124	-0.0722	-0.0524	-0.0803	-0.1175
CFE	**P**	-0.0909	-0.0556	-0.0791	-0.0749	-0.0833	0.0697	-0.0486	-0.0758	-0.0879	0.0113	-0.0472	-0.0525	-0.0052	-0.0896
	G	6.4708	4.448	6.9851	6.4438	6.0762	-6.4159	5.5292	4.8599	5.4843	-2.3453	2.215	2.7038	-0.4617	5.1324
SE	**P**	0.2964	0.1978	0.3249	0.2653	0.3041	-0.3183	0.1771	0.3174	0.3628	-0.0668	0.3171	0.3158	0.0624	0.3962
	G	-4.8169	-3.8149	-6.8149	-5.4121	-5.3241	6.8236	-5.0384	-4.8806	-5.2819	2.8012	-4.9473	-4.7227	-0.2579	-5.806
SFR	**P**	0.0552	0.0301	0.0150	0.0329	0.0368	0.0098	0.0213	0.0088	0.0121	0.0104	-0.0640	-0.0478	-0.0213	0.0012
	G	-1.8616	-0.9092	-0.3953	-1.251	-1.1633	-0.3461	-1.0681	-0.2288	-0.4606	-0.3989	2.7399	1.8804	0.7184	0.3054
TA	**P**	-0.0037	0.0088	0.0250	0.0275	0.0118	-0.0238	0.0051	0.0039	0.0112	0.0102	0.0058	0.0199	0.0313	0.0145
	G	-0.0236	0.009	0.1122	0.0835	0.0347	-0.0717	0.0405	0.0029	0.005	0.0053	-0.0023	0.0358	0.0807	0.0195
DRWP	**P**	0.6101	0.3870	0.6517	0.5939	0.6638	-0.5015	0.3526	0.7180	0.7421	-0.1978	0.2404	0.2469	-0.0163	0.6970
	G	0.6669	0.5214	0.8396	0.7510	0.6803	-0.6412	0.5678	0.7168	0.7440	-0.2755	0.2240	0.2394	-0.0534	0.7044

Table 3. Direct and indirect effects of various yield and yield attributes on root yield in 29 genotypes of ashwagandha in *Kharif*, 2018

Character		RD	NSRPP	CFE	SE	SFR	TA
PH	**P**	-0.0230	-0.0224	-0.025	-0.0159	0.0071	0.0009
	G	-0.0911	-0.0836	-0.1016	-0.0594	0.0287	0.01
NBRP	**P**	-0.0472	-0.0504	-0.0418	-0.0291	0.0106	-0.0061
	G	0.1183	0.1218	0.0961	0.0648	-0.0193	0.0052
LL	**P**	-0.0359	-0.0358	-0.0435	-0.0349	0.0039	-0.0128
	G	0.305	0.3191	0.3938	0.3018	-0.0219	0.1702
LW	**P**	0.0426	0.0457	0.0563	0.0389	-0.0116	0.0191
	G	-0.5524	-0.5993	-0.7929	-0.5232	0.1509	-0.2767
DFLI	**P**	0.1650	0.1625	0.2008	0.1432	-0.0417	0.0264
	G	0.7578	0.8221	0.994	0.6843	-0.1866	0.1527
DFF	**P**	0.0014	0.0011	0.0013	0.0011	0.0001	0.0004
	G	0.2364	0.1837	0.2313	0.1933	0.0122	0.0696
DRH	**P**	-0.0361	-0.0334	-0.0405	-0.0289	0.0083	-0.004
	G	-0.1549	-0.1825	-0.1778	-0.1273	0.0337	-0.0351
FLWP	**P**	0.3420	0.3873	0.3067	0.251	-0.0167	0.0147
	G	-0.5958	-0.7005	-0.538	-0.4245	0.0248	-0.0088
DLWP	**P**	-0.1299	-0.1394	-0.1266	-0.1021	0.0082	-0.015
	G	0.9601	1.0587	0.9403	0.7115	-0.0774	0.023

NBEP	P	-0.0080	0.0106	-0.005	-0.0057	-0.0021	0.0042
	G	-0.1671	0.0304	-0.1801	-0.169	-0.03	0.0109
BD	P	-0.0230	-0.0174	-0.0164	-0.0215	-0.0104	-0.0019
	G	-0.1581	-0.081	-0.0777	-0.1364	-0.0943	0.0022
NSPB	P	-0.0783	-0.0536	-0.0629	-0.074	-0.0269	-0.0221
	G	0.0192	0.0074	0.0119	0.0164	0.0081	0.0042
SYP	P	0.0012	0.01	0.0011	0.0027	0.0022	0.0064
	G	0.008	-0.1615	0.0291	-0.0128	-0.0443	-0.1367
MRL	P	0.0678	0.0665	0.0815	0.0704	-0.0005	0.0122
	G	0.3017	0.2484	0.3397	0.3019	0.0198	0.0347

Table 3. Direct and indirect effects of various yield and yield attributes on root yield in 29 genotypes of ashwagandha in *Kharif*, 2018

Character		RD	NSRPP	CFE	SE	SFR	TA
RD	P	**0.3063**	0.202	0.2424	0.2313	0.0338	0.0628
	G	**0.2267**	0.1447	0.1812	0.1656	0.0212	0.0454
NSRPP	P	-0.1235	**-0.1873**	-0.1363	-0.0999	0.0215	-0.0304
	G	-0.164	**-0.257**	-0.1704	-0.1161	0.0298	-0.037
CFE	P	-0.1015	-0.0933	**-0.1282**	-0.0889	0.0278	-0.0221
	G	6.5641	5.4435	**8.2116**	5.2314	-1.9038	1.2246
SE	P	0.4956	0.3499	0.4547	**0.6562**	0.3599	0.2559
	G	-7.6359	-4.7201	-6.659	**-10.4524**	-6.2868	-4.626
SFR	P	-0.0301	0.0313	0.0591	-0.1496	**-0.2727**	-0.0912
	G	0.7818	-0.9723	-1.9415	5.0367	**8.374**	3.4617
TA	P	0.0284	0.0225	0.0239	0.054	0.0463	**0.1385**
	G	0.0611	0.044	0.0455	0.135	0.1261	**0.3051**
DRWP	P	0.8137	0.6564	0.8017	0.7985	0.1471	**0.336**
	G	0.8209	0.6657	0.8357	0.8217	0.165	**0.3994**

PH - Plant height (cm); NBRP - Number of branches per plant; LL - Leaf length (cm); LW - Leaf width (cm); DFLI - Days to flower initiation; DFF - Days to fruit formation; DRH - Days to root harvest; FLWP - Fresh leaf weight per plant (g); DLWP - Dry leaf weight per plant (g); NBEP - Number of berries per plant; BD - Berry diameter (cm); NSPB - Number of seeds per berry; SYP - Seed yield per plant (g); SYH - Seed yield (q ha^{-1}); MRL - Main root length (cm); RD - Diameter of root (cm); NSRPP - Number of secondary roots per plant;DRWP - Dry root weight per plant (g);CFE - Crude fiber estimation; SE - Starch estimation; SFR - Starch and fiber ratio; TA - Total alkaloid.

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