Correlation and path analysis studies in ashwagandha \([Withania somnifera (L.) Dunal]\)

Kapil Kumar Nagar, RB Dubey, KD Ameta and Turfan Khan

DOI: [https://doi.org/10.22271/chemi.2020.v8.i5g.10341](https://doi.org/10.22271/chemi.2020.v8.i5g.10341)

Abstract

This study was aimed at probing into interrelationship among dry root yield per plant and some of its components by estimating their correlation and path coefficients. The result on phenotypic and genotypic correlation coefficient revealed that dry root yield was significantly and positively correlated with fresh root yield per plant \((r_p = 0.3343\ast\ast, r_g = 0.378\ast\ast)\) and harvest index \((r_p = 0.732\ast\ast, r_g = 0.739\ast\ast)\). However, days to flowering \((r_p = -0.203\ast\ast, r_g = -0.265\ast\ast)\) and number of primary branch per plant \((r_p = -0.166\ast, r_g = -0.252\ast)\) showed significantly and negatively correlated with dry root yield. Negative correlation of dry root yield both at genotypic and phenotypic level was seen with total alkaloid content in root \((r_p = -0.095, r_g = -0.086)\). Path coefficient analysis revealed that most of the evaluated traits exhibited positive direct effects on dry root yield per plant was exhibited by harvest index \((1.235)\) followed by dry plant weight per plant \((0.647)\), days to 75 per cent maturity \((0.134)\), number of secondary branches per plant \((0.109)\), fresh plant weight per plant \((0.102)\), leaf area index \((0.038)\), plant height \((0.016)\), root length \((0.014)\) and total alkaloid content \((0.006)\) these characters play a major role in recombination breeding and suggested that direct selection based on these traits will be rewarded for crop improvement of ashwagandha. But some characters which had negative and direct effect on dry root yield per plant followed by fresh root yield per plant, 100 seed weight, root diameter in collar region, number of primary branch per plant. The breeding methods such as selection would be effective for genetic improvement of these traits.

Keywords: Variability, correlation, path analysis

1. Introduction

Ashwagandha \([Withania somnifera (L.) Dunal]\) also known as Indian ginseng (poison) gooseberry or winter cherry is a plant of the solanaceae family (mir et al., 2013) with chromosome \(2n=48\) is native of north-western region and central India as well as Mediterranean region of north Africa. In India two species of genus withania viz., Withania somnifera \((L.) Dunal\) (ashwagandha) withania coagulans \((L.) Dunal\) (pani) are found. Withania somnifera \((L.)\) is an erect evergreen, 60-70 cm tall, under domestication and it is grown for its roots, leaves are simple ovate and opposite. The flowers are inconspicuous greenish or dull yellow and bisexual. Withania coagulans is rigid grey under shrub of 60-120 cm height. The fruit is called berry and orange/red in colour when mature. The seeds are small flat yellow and uniform in shape and very light in weight (Atal et al., 1961). It is also an in gradient of medicaments prescribed for curing disability and sexual weakness in males. Seeds are diuretic, warm leaves are used for providing comfort during eye disease (Nigam and Kandalkar, 2006). Ashwagandha is cultivated mainly in Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Punjab and Uttar Pradesh whereas Withania coagulans \((L.)\) found in wild. It is indigenous to India and is also found in Spain, Egypt, Israel, Jordan, Sudan, Iran, Afghanistan, Morocco, Baluchistan, Pakistan, Shrilanka, and Mediterranean region of east Africa. It is late kharif crop and grown under dry climate or required less irrigation for plant growth and rain fed cultivation. It is grown between 600-1200 meters altitudes. The semi tropical area receiving 60-75 cm annual rainfall with high temperature 20°C to 35°C is suitable for its cultivation. Ashwagandha is grown on marginal lands of Neemach and Mandsaur district of M.P. and Kota, Jhalawar, Pratapgarh, Chittorgarh and Baran districts of Rajasthan. The medicinal utility of roots is due to present of number of alkaloids. The total alkaloids content in the roots varied from 0.16 to 0.66 percent (Biennial Progress Report of AICRP on Medicinal & Aromatic Plant, 2006-08).
2. Material and Method
The Experiment was laid out late kharif-2017 in the Botany farm at Rajasthan college of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur to assess genetic divergence among sixty three genotypes with three standard check (JA-20, JA-134 and RVA-100) by growing them in a Randomized Block Design (RBD) with three replications a single row plot of 4.0 meter length maintaining a crop geometry of 30 X 5 cm. The correlations among various variables and the path coefficient were estimated as per the procedure of Dewy and Lu (1959)\textsuperscript{[10].}

3. Result & Discussion
3.1 Correlation between dry root yield per plant and other characters:
The correlation between dry root yield per plant with different yield attributes and amongst the attributes themselves are presented in the Table 1. The correlation analysis revealed that dry root yield per plant was highly significant and positively correlated phenotypic as well as genotypic level with fresh root yield per plant (rp = 0.3343*, rg = 0.378**) and harvest index (rp = 0.732**, rg = 0.739**). The similar results were also reported by Kubsad et al., (2009)\textsuperscript{[15]}, Kumar et al., (2011), Joshi et al (2013), Sukhdev et al., (2015) and Sundesh et al., (2016). Dry root yield per plant was negatively and significantly correlated at both phenotypic as well as genotypic level with days to flowering (rp = -0.203*, rg = -0.265**) and number of primary branch per plant (rp = -0.160*, rg = -0.252*). Negative correlation of dry root yield both at genotypic and phenotypic level was seen with total alkaloid content in root (rp = -0.095, rg = -0.086).The similar results were also reported by Sukhdev et al. (2015) and Sundesh et al. (2016).

Days to flowering showed significant correlation in positive direction at both phenotypically and genotypically level with number of primary branch per plant (rp = 0.164*, rg = 0.212*). However, days to flowering also showed significant and negative correlation at both phenotypically and genotypically level with root length (rp = -0.162*, rg = -0.258*), dry plant weight per plant (rp = -0.238**, rg = -0.310**) and fresh plant weight per plant (rp = -0.188**, rg = -0.231**). The similar results were also reported by Patel and Desai et al. (2017).

Days to 75 per cent maturity exhibited significant and positive correlation at both phenotypically and genotypically level with fresh plant weight per plant (rp =0.182*, rg = 0.448 *). The similar results were also reported by Gami et al. (2016)\textsuperscript{[10].}

The number of secondary branch per plant showed significant and negative correlation at both phenotypically and genotypically level with 100 seed weight (rp = -0.146*, rg = -0.238*). The similar results were also reported by Sundesh et al. (2016)

The number of secondary branch per plant showed significant and negative correlation at both phenotypically and genotypically level with fresh root yield per plant (rp = -0.219**, rg = -0.311**). The similar results were also reported by Sundesh et al. (2016). The root length showed significant and negative correlation at both phenotypically and genotypically level with root diameter in collar region (rp = -0.151*, rg = -0.192*) and leaf area index (rp = -0.159*, rg = -0.205*) The similar results were also reported by Kumar et al. (2011) and Sundesh et al. (2016). The fresh root yield per plant showed significant and positive correlation at both phenotypically and genotypically level with harvest index (rp = 0.279**, rg = 0.303**) and also showed significant and negative correlation with leaf area index (rp = -0.181*, rg = -0.218*). The similar results were also reported by Kumar et al. (2012)\textsuperscript{[17].}

The dry plant weight per plant showed significant and positive correlation at both phenotypically and genotypically level with fresh plant weight per plant (rp = 0.666**, rg = 0.751**) and also showed significant and negative correlation with harvest index (rp = -0.608**, rg = -0.628**). The fresh plant weight per plant showed significant and negative correlation at both phenotypically and genotypically level with (rp = -0.340**, rg = -0.411**).

Leaf area index showed significant and positive correlation at both phenotypically and genotypically level with 100 seed weight (rp = 0.181*, rg = 0.263*).

3.2 Path coefficient analysis
Path coefficient analysis was worked out to get an insight into the direct and indirect effects of 14 dependent characters on dry root yield and the results are presented in the Table 2.

3.3 Direct effects
Out of fourteen characters, nine characters showed positive and direct effect on fresh root yield per plant at genotypic level. The highest positive direct effect on dry root yield per plant was exhibited by harvest index followed by dry plant weight per plant, days to 75 per cent maturity, number of secondary branches per plant, fresh plant weight per plant, leaf area index, plant height, root length and total alkaloid content. The characters which had negative and direct effect on dry root yield, days to flowering followed by fresh root yield per plant, 100 seed weigh, root diameter in collar region, number of primary branch per plant, respectively. The similar results were also reported by Kubsad et al. (2009)\textsuperscript{[15].}

3.4 Indirect effects
Dry plant weight per plant (0.486) and days to flowering (0.033) exhibited considerable positive indirect effect on dry root yield per plant through fresh plant weight but harvest index (-0.508) and number of secondary branch per plant (-0.015) showed considerable negative indirect effect on it through fresh plant weight per plant. Harvest index (0.375) followed by days to 75 per cent maturity (0.060), dry plant weight per plant (0.0127) and fresh plant weight per plant (0.0121) exhibited considerable positive indirect effect on dry root yield per plant through fresh plant weight per plant but (-0.033) and leaf area index (-0.008) showed considerable negative indirect effect on it via fresh plant weight per plant. The similar results were also reported by Kubsad et al., (2009)\textsuperscript{[15].}
### Table 1: Genotypic and phenotypic correlation between dry root yield per plant and other characters studied in Ashwagandha

| Character                               | Days to flowering | Days to 75% maturity | Plant height | No. of primary branches/plant | No. of secondary branches/plant | Root length | Fresh root yield/plant | Root diameter in collar region | Dry plant weight/plant | Fresh plant weight/plant | Harvest index | Leaf area index | Total alkaloid content | 100-seed weight | Dry root yield/plant |
|----------------------------------------|------------------|----------------------|--------------|-------------------------------|-------------------------------|-------------|-------------------------|-------------------------------|-------------------------|-------------------------|---------------|----------------|----------------------|---------------|----------------------|
| Days to Flowering                      | G: 1.0000        | P: 1.0000            | G: 0.1551    | G: 0.2125*                    | G: -0.0456                   | G: -0.2587* | G: -0.0208              | G: 0.0930                     | G: -0.3106**             | G: -0.2314*              | G: 0.0700      | G: -0.0553      | G: 0.0078             | G: -0.0870      | G: -0.2650**          |
| Day to 75% Maturity                    | G: 1.0000        | P: 1.0000            | G: 0.1082    | G: 0.1643*                    | G: -0.0245                   | G: -0.1622* | G: -0.0885              | G: 0.0808                     | G: -0.2380**             | G: -0.1884*              | G: 0.0455      | G: -0.0516      | G: 0.0172             | G: -0.0820      | G: -0.2034**          |
| Plant Height                           | G: 1.0000        | P: 1.0000            | G: 0.0377    | G: -0.1596                    | G: -0.2471                   | G: 0.1286   | G: 0.4484*              | G: 0.2081                     | G: 0.0568                | G: -0.1120                | G: -0.1181     | G: -0.3430      | G: -0.3156            | G: 0.5108       | G: -0.1175            |
| Number of Primary Branches/Plant       | G: 1.0000        | P: 1.0000            | G: 0.0421    | G: -0.0391                    | G: -0.0822                   | G: 0.0766   | G: 0.1829*              | G: 0.0884                     | G: 0.0102                | G: -0.0570                | G: -0.0945     | G: -0.1232      | G: -0.1230            | G: 0.1021       | G: -0.0980            |
| Number of Secondary Branches/Plant     | G: 1.0000        | P: 1.0000            | G: 0.0947    | G: -0.1649*                   | G: 0.0687                     | G: 0.0477   | G: 0.1627*              | G: -0.1835*                   | G: -0.1230               | G: 0.1116                | G: -0.1255     | G: 0.1515*      | G: -0.0813            | G: -0.0172      |                    |
| Root Length                            | G: 1.0000        | P: 1.0000            | G: 0.0352    | G: 0.0209                     | G: -0.1317                   | G: -0.0660  | G: 0.0604               | G: 0.0415                     | G: -0.1312               | G: -0.0179                | G: 0.0764      | G: 0.1465*      | G: -0.1602*           |                    |                    |
| Fresh Root Yield/Plant                 | G: 1.0000        | P: 1.0000            | G: 0.1856    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Root Diameter in Collar Region         | G: 1.0000        | P: 1.0000            | G: 0.0566    | G: 0.1824*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Dry Plant Weight/plant                 | G: 1.0000        | P: 1.0000            | G: 0.0478    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Harvest Index                          | G: 1.0000        | P: 1.0000            | G: 0.0517    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Leaf Area Index                        | G: 1.0000        | P: 1.0000            | G: 0.0566    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Total Alkaloid content                 | G: 1.0000        | P: 1.0000            | G: 0.0478    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| 100 Seed Weight                       | G: 1.0000        | P: 1.0000            | G: 0.0566    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
| Dry Root Yield/plant                   | G: 1.0000        | P: 1.0000            | G: 0.0566    | G: 0.1518*                    | G: -0.1403                   | G: 0.0153   | G: 0.1424               | G: -0.1410                   | G: 0.1459                | G: -0.0262                | G: 0.0436      | G: -0.0893      |                    |                    |                    |
Table 2: Direct and indirect effects of different correlated characters towards dry root yield per plant in Ashwagandha

| Character                        | Day to flowering | Day to 75% maturity | Plant height cm | Number primary branches/ Plant | Number secondary branches/ Plant | Root length (cm) | Fresh root yield g/plant | Root diameter in collar region | Dry plant weight /plant | Fresh plant weight /plant | Harvest Index | Leaf area index | Total alkaloid content | 100 Seed weight | Dry root yield |
|---------------------------------|------------------|---------------------|-----------------|-------------------------------|---------------------------------|----------------|--------------------------|-------------------------------|--------------------------|---------------------------|-----------------|----------------|---------------------|----------------|-----------------|
| Day to Flowering                | -0.1451          | -0.0337             | -0.0225         | -0.0308                       | 0.0066                          | 0.0375          | 0.003                    | -0.0135                       | 0.045                    | 0.0336                    | -0.0102        | 0.008         | -0.0011             | 0.0126         | -0.265         |
| Day to 75% Maturity             | 0.0313           | 0.1349              | 0.0051          | -0.0215                       | -0.0333                        | 0.0174          | 0.0605                   | 0.0281                        | 0.0077                   | -0.0151                    | -0.0159        | -0.0463       | 0.0689               | -0.1175        | -0.426         |
| Plant Height cm                 | 0.0026           | 0.0006              | 0.0166          | 0.001                          | -0.0039                        | 0.0022          | 0.0001                   | 0.0038                        | -0.0037                  | -0.0021                    | 0.002          | -0.0031       | 0.0034               | -0.0004        | -0.0512        |
| Number of Primary Branches/ Plant | -0.0056       | 0.0042              | -0.0016         | -0.0264                       | 0.0007                         | -0.0023         | 0.0059                   | 0.0011                        | -0.0018                  | -0.0005                    | 0.0053         | 0.0007        | -0.0027              | 0.0063         | -0.2525        |
| Number of Secondary Branches/ Plant | -0.005           | -0.0269            | -0.0253         | -0.003                        | 0.109                          | -0.0178         | -0.0339                  | 0.0199                        | 0.0017                   | -0.0155                    | -0.0153        | 0.0159        | -0.0029              | 0.0048         | -0.0893        |
| Root Length (cm)                | -0.0038          | 0.0019              | 0.0019          | 0.0013                        | -0.0024                       | 0.0145          | 0.0027                   | -0.0028                       | 0.0002                   | 0.0002                    | -0.003         | 0.0019        | 0.0017               | 0.1911         | -0.387         |
| Fresh Root Yield g/Plant        | 0.0012           | -0.0257             | -0.0004         | 0.0128                        | 0.0178                        | -0.0106         | -0.0573                  | 0.0021                        | -0.0011                  | -0.0068                    | 0.0174         | 0.0125        | 0.0076               | 0.0522         | 0.3782         |
| Root Diameter In Collar Region  | -0.0048          | -0.0107             | -0.0116         | 0.0021                        | -0.0093                       | 0.0099          | 0.0019                   | -0.0512                       | -0.0024                  | -0.0004                    | 0.0023         | 0.0017        | -0.0013              | -0.0387        | -0.387         |
| Dry Plant Weight/plant          | -0.201           | 0.0368              | -0.1425         | 0.0444                        | 0.0099                        | -0.0908         | 0.0127                   | 0.031                         | 0.6472                   | 0.4866                     | -0.407         | -0.034        | -0.0173              | 0.0418         | -0.0417        |
| Fresh Plant Weight/plant        | -0.0238          | -0.0115             | -0.0128         | 0.002                          | -0.0146                       | 0.0012          | 0.0121                   | 0.0008                        | 0.0772                   | 0.1027                    | -0.0423        | -0.0084       | -0.0056              | -0.0059        | 0.0733         |
| Harvest Index                   | 0.0865           | -0.146              | 0.1465          | -0.2462                       | 0.1731                        | 0.2447          | 0.375                    | -0.0551                       | -0.7769                  | -0.5089                    | 1.2356         | -0.0342       | -0.0373              | 0.7394         | -0.0379        |
| Leaf Area Index                 | -0.0021          | -0.0133             | -0.0073         | -0.001                        | 0.0056                        | -0.008          | 0.0085                   | -0.0013                       | -0.0002                  | -0.0032                    | 0.0011         | 0.0387        | 0.0111               | -0.0648        | -0.957         |
| Total Alkaloid content          | 0               | -0.002              | 0.0013          | 0.0006                        | -0.0002                       | -0.0008         | 0.0008                   | -0.0003                       | -0.0002                  | 0.0002                     | 0.0002         | 0.0604        | 0.0006               | -0.0957        | -0.957         |
| 100 Seed Weight                 | 0.0045           | -0.0262             | 0.0012          | 0.0122                        | -0.0022                       | -0.0059         | 0.0047                   | -0.0013                       | -0.0033                  | 0.0003                     | 0.0007         | -0.0135       | -0.0051              | 0.0755         | 0.0513        |

Residual effect = 0.3059  ** Significant at level 1% level, Bold value indicate direct effect
Harvest index (0.244) and days to flowering (0.037) and days to 75% maturity (0.017) exhibited considerable positive indirect effect on dry root yield per plant through root length but dry plant weight per plant (-0.09) and fresh root yield per plant (-0.010) showed considerable negative indirect effect on it through root length. The similar results were also reported by Kubsad et al., (2009) [13].

Harvest index (0.146) followed by days to 75 per cent maturity (0.005) and root length (0.0019) exhibited considerable positive indirect effect on dry root yield per plant through plant height but dry plant weight per plant (0.142) and number of secondary branch (-0.025) showed considerable negative indirect effect on it on plant height. Harvest index (0.086) and days to 75 per cent maturity (0.031) exhibited considerable positive indirect effect on dry root yield per plant through days to flowering but dry plant weight per plant (-0.201) and fresh plant weight per plant (-0.023) showed considerable negative indirect effect on it through days to flowering. The residual effect on dry root yield per plant was 0.30 indicated that 99.70 per cent of variability was governed by above said character and 0.30 per cent variability was due to environment effect.

5. Reference
1. Al-Jibouri HA, Miller PA, Robison HF. Genotype and environmental variances and covariances in an upland cotton cross of inter-specific origin. Agronomy Journal, 1958; 50:633-636.
2. Allard RW. Principle of Plant Breeding. John Wiley and Sons, Inc. New York, 1960.
3. Burton GW. Quantitative inheritance in grasses. Proceedings of 6th International Grassland Congress, 1952; 1:277-288. From replicated clonal materials. Agronomy Journal, 45:478-481.
4. Chaudhary SB, Bagul RS, Dodake SS. Genotypic Association and Path Co-efficient Analysis in Ashwagandha [Withania Somnifera (L.) Dunal], International Journal of Medical Sciences. 2016; 9:81-83.
5. Das A, Datta AK, Ghose S, Bhattacharyya A. Genetic analysis in Poshita and Jawahar-22 varieties of Withania somnifera (L.) Dunal. Plant Archives. 2011; 11:59-62.
6. Dewey DR, Lu KH. A correlation and path coefficient analysis of components of crested wheat grass and seed production. Agronomy Journal. 1959; 51:515-517.
7. Dubey RB. Genetic variability, correlation and path analysis in Ashwaganda (Withania somnifera). Journal of Medicinal and Aromatic Plant Sciences. 2010; 32(3):202-205. 8.
8. Fisher RA. The correlation between relatives on the supposition of mendelian inheritance. Philosophical Transaction Royal Society of Edinburg. 1918; 62:399-433.
9. Fisher RA, Yates F. Statistical tables for biological, agricultural and medical research, (3rd ed), London, Oliver and Boyd. 1938, 26-27.
10. Gami RA, Solanki SD, Patel MP, Tiwari K, Bhadauria HS, Kumar M. Correlation study in ashwagandha (Withania somnifera L. Dunal) and identify better genotypes for north Gujarat. Advances in Life Sciences, 2016; 5:2844-2848.
11. Galton CF. Natural inheritance. MAc. Millan, London Publications, 1889.
12. Gupta AK, Verma SR, Gupta MM, Saikia D, Verma RK, Jhang T. Genetic diversity in germplasm collections of Withania somnifera for root and leaf alkaloids. Journal of Tropical Medicinal Plants. 2011; 12:59-69.
13. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soyabean. Agronomy Journal. 1955; 47:314-318.
14. Kandalkar VS, Patidar H, Nigam KB. Genotypic association and path coefficient analysis in ashwagandha (Withania somnifera). The Indian Journal of Genetics and Plant Breeding. 1993; 53:257-260.
15. Kubsad VS, Palled YB, Mansur CP, Alagundagi SC. Correlation and Path Coefficient Analysis in Ashwagandha (Withania somnifera Dunal). Madras Agric. J. 2009; 96:314-315.
16. Kubsad VS, Mansur CP, Alagundagi SC. Genetic associations and path analysis in ashwagandha (Withania somnifera) under varied production practices. Journal of Medicinal and Aromatic Plant Sciences. 2011; 33(2):172-175.
17. Kumar V, Kumar N, Singh MC. Correlation coefficient studies in ashwagandha (Withania somnifera Dunal) cv. JAWAHAR-20 Hort Flora Research Spectrum. 2012; 1:354-357.
18. Laxminarayan H, Mukund S. Genetic variability in ashwagandha (Withania somnifera). In: National Seminar on new perspectives in spices, medicinal and aromatic plants, 27-29 November, Goa. 2003, 19.
19. Lush JL. Animal Breeding Plans, (3rd ed). Iowa State University Press, Ames, IA, 1945, 443.
20. Mahalanobis PC. On the generalized distance in statistics. Proceedings of National Academic Science (India). 1936; 2:79-85.
21. Mishra HO, Sharma JR, Lal RK, Sharma S. Genetic variability and path analysis in ashwagandha (withania somnifera L.). Journal of Medicinal and Aromatic Plant Sciences. 1998; 20:753-756.
22. Mohsina Iqbal, Datta AK. Genetic variability, correlation and path analysis in Withania somnifera (L.) Dunal. (Ashwagandha). Journal of Phytological Research. 2007; 20:119-122.
23. Panse VG. Genetics of quantitative characters in relation to plant breeding. Indian journal of genetics. 1957; 17:318-328.
24. Panse VG, Sukhate MV. Statistical methods for agricultural workers, ICAR Publ., (4th ed), New Delhi, 1985, 63-66.
25. Rao CR. Advanced statistical Methods in Biometrical Research. John Wiley and Sons, Inc., New York: 1952, 390.
26. Sangwan O, Avtar R, Singh A. Genetic variability, character association and path analysis in Ashwagandha (Withania somnifera (L.) Dunal) under rainfed conditions. Research in Plant Biology. 2013; 3:32-36.
27. Singh RK, Chaudhary BD. Biometrical methods in quantitative genetics analysis. Kalyani publishers, New delhi, India, 1979
28. Sukh Dev, Dubey RB, Ameta KD. Studies on variability and character association in Ashwagandha (Withania somnifera (L.) Dunal) Progressive Horticulture. 2015; 47:154-157.
29. Wright S. Correlation and causation. Journal of Agricultural Research. 1921; 20:555-586.
30. Wright S. The analysis of variance and the correlations between relatives with respect to deviations from an optimum. Journal of Genetics. 1935; 30:243-256.
31. Yadav OP, Kumar Y, Verma PK. Genetic variability, association among metric traits and path coefficient analysis in Ashwagandha (Withania somnifera). Haryana Agriculture University Journal of Research. 2008; 38:23-26.