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To assess the extent of path coefficient via direct and indirect effects of yield contributing trait in Tuberose

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Abstract
In the present investigation, at the Horticultural Research Centre, Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (UP), during the year of 2015-2016 on “To assess the extent of path coefficient via direct and indirect effects of yield contributing trait”. All twenty-two genotypes were grown in randomized block design with 3 replications with row to row and plant to plant spacing of 30 cm and 20 cm, respectively during 2015-16. Observations were recorded on various characters viz; days taken to sprouting, plant height, number of leaves per plant, length of longest leaf, width of longest leaf, number of sprouts per bulbs, days required for visibility of first spike, days taken to opening of first flower, number of florets per spike, diameter of flower, number of spike per bulb, diameter of spike, length of spike, length of rachis, longevity of spike, vase life, number of bulbs per plant, number of bulblets per plant, yield of bulb per plant, diameter of bulb, yield of bulb and bulblets per plant, yield of bulb.

Keywords: path coefficient, indirect effects, yield contributing

Introduction
India is bequeathed with numerous agro-climatic zones favorable for production of delicate and gentle floriculture harvests. Now a day’s floriculture is fast emerging sector as a major venture on the world scenario. Consequently, flower cultivation is recognized as most remunerative living with a much higher potential for return per unit area than other field crops.
The tuberose (*Polianthes tuberosa* Linn.), is a night-blooming perennial plant, belongs to the family Asparagaceae and thought to be native to Mexicoalong with every other species of *Polianthes* (Benschop, 1993) [6]. The common name of *Polianthes tuberosa* derives from the Latin *tuberosa*, meaning swollen or tuberous in reference to its root system and *Polianthes* means "many flowers" in Greek language. It consists of about 12 species.
The area under floriculture production in India was 255.00 thousand hectares with a production of 1,754 thousand metric tons loose flowers and 543 thousand metric tons cut flowers during 2013-14 (Anonymous, 2015) [1]. Floriculture is now commercially cultivated in several states with West Bengal (32%), Karnataka (12%) Maharashtra (10%), having gone ahead of other producing states like Madhya Pradesh, Gujarat, Punjab, Haryana, Andhra Pradesh, Orissa, Jharkhand, Uttar Pradesh and Chhattisgarh. India's total export of floriculture was Rs. 455.90 crores in 2013-14. The major importing countries were United States, Netherlands, Germany, United Kingdom, United Arab Emirates, Japan and Canada.
The flowers of tuberose produce one of the rarest and most valuable aromas with sweet and pleasant fragrance. In the last two decades or so a few new tuberose cultivars have been identified and recommended for commercial cultivation in different regions of our country. Several cultivars had been assessed and evaluated for their performance under different regions of the country taking single petalled and double petalled cultivars together by Bankar and Mukhopadhyay (1980) [5], Bhattacharjee *et al.*, (1981) [7], Pratap and Manohar Rao (2003) and Singh and Misra (2005) [14] and have revealed that a market demand has increased manifold for want of diverse forms and intense fragrance found in them.
The knowledge about the factors responsible for yield is a difficult problem as yield is a complex character and an interactive effect multiplication of different traits. Therefore, for achievement of high yield level, the breeder is required to simplify this complex situation.

Thus the study of correlation between yield and its components is of prime importance in formulating the selection criteria. Selection is generally based on the phenotypic values of a character which partly determined by genotypes which is heritable, and partly by environment which is non-heritable. The characters that are largely influenced by environment are said to have low heritability while those which are less susceptible to environment variation shows high heritability. Paroda and Joshi (1970) [11] referred the idea about heritability. Therefore, it is necessary to know the various components of yield, their heritable and non-heritable variability and their mutual correlation.
The study of genetic advance is equally important as it measures the genetic gain based on selection in a particular character. Therefore, any crop improvement programme through selection, the study of genetic variability and heritability together with genetic advance is necessary. A number of variables are studied in correlation, which give an idea about indirect selection. Indirect selection is equally important in influencing the final product, grain yield in any crop species. For this, path coefficient analysis has emerged as a very strong tool as it determines the direct and indirect causes of association giving the idea of specific forces which act to produce strong correlation and measures relative importance of each causal factor.

Materials and Methods

Path coefficient analysis

The analysis of path-coefficient was conducted following the procedure suggested by Wright (1921) and as elaborated by Dewey and Lu (1959).
Fourteen yield contributing characters were considered in path coefficient analysis to estimate their direct and indirect effect on seed yield.
Path coefficients were obtained by solving the simultaneous equation which expresses the basic relationship between correlation and path coefficient. The equation is as follows:

ry1 = Py1 + Py1r12 +Py3r13 + ……………….Pynr1n
ry2 = Py2 + Py1r21 +Py3r23 + ……………….Pynr2n
ryn = Pyn + Py1rn1 +Pynrn2 + ……………….Pynrn(n-1)

Where,
ry1, ry2……………. ryn are the correlation coefficient of dependent variable (y) with various independent variables (1, 2,...... n).

Py1, Py2…………..Pyn are the direct path effects of independent variables (1, 2,............n) on dependable variable (y).

r12, r13………………. r1n…………..rn(n-1) are the correlation coefficient between various independent variables (1, 2,……..n).

Path coefficients were obtained by replacing the corresponding elements in A and B matrix by correlation coefficients. B matrix was inverted and the inverted B matrix was multiplied by matrix to obtain path coefficients.
Residual factor which measures the contribution of rest on the characters of causal scheme was obtained as given below:

$Pxy = \sqrt{1-R^2}$

Where, $R^2 = \sum i = 1Piy\ riy$

Where riydenotes correlation between all possible combinations of independent character Y. The correlation is r12 to r11 12 P = direct effect of ith character on Y. riy = coefficient correlation between ith and y factor.

Result

Path coefficient analysis

Partitioning of the correlation coefficient of the various characters under study was done with the help of the path coefficient analysis to express the direct and indirect effect of growth and yield parameters with bulb yield. The results obtained at genotypic and phenotypic level are presented in table 1, 2 3 and 4.
At genotypic level, Maximum positive direct effect was observed for Plant height (4.407) followed by days taken to opening of first flower (3.326), days taken to sprouting (0.559). Negative direct effect was observed for length of longest leaf (-4.875), days required for visibility of first spike (-3.094) and number of leaves per plant (-0.721).
Days taken to sprouting recorded positive correlation and highly significant with yield of bulb (0.723). Direct effect of days taken to sprouting on yield of bulb was observed (0.559). No indirect effect was shown.
Plant height revealed positive and highly significant with bulb yield (0.321). Direct effect of plant height on yield of bulb (4.407). Indirect effect of this character was observed negative with number of leaves per plant (-1.238).
Number of leaves per plant showed negative correlation with yield of bulb (-0.131). It showed negative direct effect on yield of bulb (-0.721). Indirect effect of this character was observed in days taken to sprouting (-0.360), width of longest leaf (-0.217), number of sprouts per bulb (-0.465), number of florets per spike (-0.120), diameter of flower (-0.031) and number of spikes per bulb (-0.230)
Length of longest leaf showed positive and highly significant correlation with bulb yield (0.309). It showed negative direct effect on yield of bulb (-4.895). Indirect effect was observed negative vial all the characters except number of leaves per plant (1.326).
Width of longest leaf showed positive and highly significant correlation on bulb yield (0.352). It revealed negative direct effect on bulb yield (-0.097). The indirect effect was observed in days taken to sprouting (-0.016), plant height (-0.031), number of leaves per plant (-0.029), length of longest leaf (-0.031), number of sprouts per bulb (-0.043), number of florets per spike (-0.054) and number of spikes per bulb (-0.028).
Number of sprouts per bulb revealed positive correlation effect on bulb yield (0.107). Positive direct effect showed on yield of bulb (0.378). Indirect effect showed in days required for visibility of first spike (-0.102) and days taken to opening of first flower (-0.087).
Days required for visibility of first spike showed positive and highly significant correlation effect on bulb yield (0.366). It showed negative direct effect on bulb yield (-3.094). Indirect effect was observed in days taken to sprouting (-0.318), plant height (-1.876), length of longest leaf (-1.864), days taken to opening of first flower (-3.087), number of florets per spike (-0.944) and diameter of flower (-0.727).
Days taken to opening of first flower showed positive and highly significant correlation effect on bulb yield (0.346). Direct effect on bulb (3.326). Indirect effect was observed in number of leaves per plant (-2.081), width of longest leaf (-0.369), number of sprouts per bulb (-0.762) and number of spikes per bulb (-0.924).

Number of florets per spike revealed positive and highly significant correlation effect on bulb yield (0.719). Direct effect showed on bulb yield (0.531). It does not show indirect effect with any characters.
Diameter of flower showed negative correlation effect on bulb yield (-0.232). It exhibited negative direct effect on bulb yield (-0.561). Indirect effect revealed via all characters except width of longest leaf (0.068) and number of spikes per bulb (0.150).
Number of spikes per bulb showed positive and highly significant on bulb yield (0.508). Positive direct effect on bulb yield (0.194). The indirect effect exhibited in days required for visibility of first spike (-0.041), days taken to opening of first flower (-0.054) and number of spikes per bulb (0.194).
Diameter of spike showed positive correlation effect on bulb yield (0.197). Negative direct effect on bulb yield (-0.236). Indirect effect was observed in via all characters except diameter of bulb (0.097).
Length of spike showed negative correlation effect on bulb yield (-0.004). Positive direct effect on bulb yield (0.330). Indirect effect showed in diameter of bulb (-0.020)
Length of rachis showed negative correlation effect on bulb yield (-0.109). Negative direct effect on bulb yield (-0.130). The indirect effect was observed in diameter of spike (-0.020), length of spike (-0.080), longevity of spike (-0.030), number of bulbs per plant (-0.030) and number of bulblets per plant (-0.020).
Longevity of spike showed negative correlation effect on bulb yield (-0.110). Negative direct effect on bulb yield (-0.400), Indirect effect was observed in diameter of spike (-0.040), length of spike (-0.090) and length of rachis (-0.080).
Vase life exhibited positive correlation effect on bulb yield (0.154). Positive direct effect on bulb yield (0.114). Indirect effect was observed in none of the characters.
Number of bulbs per plant showed positive and highly significant correlation effect on bulb yield (0.640). Negative direct effect on bulb yield (-0.126). Indirect effect was observed in diameter of spike (-0.030), length of rachis (-0.100), number of bulblets per plant (-0.044) and yield of bulb per plant (-0.031).
Number of bulblets per plant show positive and highly significant correlation effect on bulb yield (0.634). Negative direct effect on bulb yield (-0.013). Indirect effect was recorded in diameter of spike (-0.030), length of spike (-0.040), length of rachis (-0.050), number of bulbs per plant (-0.132), yield of bulb per plant (-0.220) and yield of bulbs and bulblets per plant (-0.024).
Yield of bulb per plant showed positive and highly significant effect on bulb yield (0.998). Positive direct effect on bulb yield (0.452). Indirect effect showed none of the characters.
Diameter of bulb showed positive and highly significant correlation on bulb yield (0.346). Negative direct effect on bulb yield (-0.200). Indirect effect was observed in vase life (-0.160), yield of bulb per plant (-0.070) and yield of bulb and bulblets per plant (-0.070).
Yield of bulb and bulblets per plant showed positive and highly significant correlation on bulb yield (0.998). Positive direct effect on bulb yield (0.645). Indirect effect was observed in length of rachis (-0.011) and longevity of spike (-0.010).
At phenotypic level, maximum positive direct effect was observed for plant height (0.780) followed by number of florets per spike (0.517). Negative direct effect was observed for length of longest leaf (-0.943), days taken to opening of first flower (-0.224), number of leaves per plant (-0.222).
Days taken to sprouting revealed positive correlation and highly significant with bulb yield (0.338), direct effect of days taken to sprouting on yield of bulb (0.138). Indirect effect was observed with none of the characters.
Plant height revealed positive and highly significant correlation on yield of bulb (0.295). Direct effect on yield of bulb (0.780). Indirect effect was observed in number of leaves per plant (-0.162).
Number of leaves per plant showed negative effect on bulb yield (-0.091). It showed negative direct effect on bulb yield (-0.222). Indirect effect was observed in days taken to sprouting (-0.080), width of longest leaf (-0.051), number of sprouts per bulb (-0.130), number of florets per spike (-0.027), diameter of flower (-0.016) and number of spikes per bulb (-0.065).
Length of longest life showed positive and highly significant correlation on yield of bulb (0.284). It revealed negative direct effect on yield of bulb (-0.943). Indirect effect was observed in via all characters except number of leaves per plant (0.177).
Width of longest leaf revealed positive and highly significant correlation on yield of bulb (0.276). Direct effect on yield of bulb (0.081). Indirect effect was observed in days required for visibility of first spike (-0.013), days taken to opening of first flower (-0.009) and diameter of flower (-0.003).
Number of sprouts per bulb showed positive correlation on bulb yield (0.078). Direct effect on yield of bulb (0.104). Indirect effect was observed in days required for visibility of first spike (-0.025) and days taken to opening of first flower (-0.017).
Days required for visibility of first spike showed positive and highly significant correlation on yield of bulb (0.341). Direct effect showed on bulb yield (0.512). The indirect effect was observed in number of leaves per plant (-0.283), width of longest leaf (-0.080), number of sprouts per bulb (-0.121) and number of spikes per bulb (-0.108).
Days taken to opening of first flower showed positive and highly significant correlation on yield of bulb (0.281), Negative direct effect on yield of bulb (-0.224). Indirect effect was observed in days taken to sprouting (-0.001), plant height (-0.127), length of longest leaf (-0.126), days required for visibility of first spike (-0.204), number of florets per spike (-0.070) and diameter of flower (-0.047).
Number of florets per spike showed positive and highly significant correlation on yield (0.647). Positive direct effect on bulb yield (0.517). Indirect effect was observed none of the characters.
Diameter of flower showed negative correlation on yield of bulb (-0.163). Negative direct effect on bulb yield (-0.169). Indirect effect was observed in the all characters except width of longest leaf (0.006) and number of spikes per bulb (0.033).
Number of spikes per bulb showed positive and highly significant correlation on bulb yield (0.483). Direct effect on bulb yield (0.360). Indirect effect was recorded in days required for visibility of first spike (-0.076), days taken to opening of first flower (-0.086) and diameter of flower (-0.070).
Diameter of spike revealed positive correlation on bulb yield (0.183). Negative direct effect on bulb yield (-0.023). Indirect effect was observed in via all characters except yield of bulb per plant (0.001).
Length of spike revealed negative correlation on bulb yield (-0.008). Positive direct effect on bulb yield (0.013). Indirect effect was observed none of the characters.

Length of rachis showed negative correlation on bulb yield (-0.092). Negative direct effect on bulb yield (-0.217). Indirect effect was observed in diameter of spike (-0.005), length of spike (-0.070), longevity of spike (-0.002), vase life (-0.060), number of bulbs per plant (-0.040) and yield of bulb and bulblets per plant (-0.053).
Longevity of spike revealed negative correlation effect on bulb yield (-0.090). Negative direct effect on bulb yield (-0.048). Indirect effect was recorded in diameter of spike (-0.001), length of spike (-0.003), length of rachis (-0.004) and yield of bulb and bulblets per plant (-0.002).
Vase life showed positive correlation effect on bulb yield (0.116). Negative direct effect showed on bulb yield (-0.050). Indirect effect was observed in number of bulbs per plant (-0.030).
Number of bulbs per plant showed positive and highly significant correlation on bulb yield (0.613). Positive direct effect on bulb yield (0.020). No indirect effect was shown.
Number of bulblets per plant showed positive and highly significant correlation on bulb yield (0.606). Positive direct effect on bulb yield (0.170). Indirect effect was observed in length of rachis (-0.002), longevity of spike (-0.001) and yield of bulb per plant (-0.100).
Yield of bulb per plant showed positive and highly significant correlation on bulb yield (0.998). Positive direct effect on bulb yield (0.245). Indirect effect was exhibited in longevity of spike (-0.243).
Diameter of bulb revealed positive and highly significant correlation effect on bulb yield (0.252). Negative direct effect on bulb yield (-0.050). Indirect effect was observed in longevity of spike (-0.004), vase life (-0.001), number of bulblets per plant (-0.005) and yield of bulb per plant (-0.319).
Yield of bulb and bulblets per plant revealed positive and highly significant on bulb yield (0.997). Positive direct effect on bulb yield (0.714). Indirect effect was observed via in all the characters except length of rachis (0.015).

Table 1: Path coefficient analysis showing the direct and indirect effect of twenty-two characters on the yield of bulb at genotypic level of tuberose.

Characters	Days taken to sprouting	Plant height (cm)	No. of leaves per plant	Length of longest leaf (cm)	Width of longest leaf (cm)	No. of sprouts per bulb	Days required forvisibility of first spike	Days taken to opening of first flower	No. of florets per spike	Dia-meter of flower (cm)	No. of spikes per bulb	Yield of bulb (q/ha)
Days taken to sprouting	0.559	1.368	-0.360	-1.473	-0.016	0.184	-0.318	0.405	0.361	-0.118	0.132	0.723**
Plant height (cm)	0.173	4.407	0.203	-4.895	-0.031	0.111	-1.876	2.161	0.188	-0.141	0.021	0.321**
No. of leaves per plant	0.279	-1.238	-0.721	1.326	-0.029	0.244	1.963	-2.081	0.088	-0.024	0.062	-0.131
Length of longest leaf (cm)	0.168	4.407	0.195	-4.895	-0.031	0.110	-1.864	2.147	0.193	-0.144	0.021	0.309*
Width of longest leaf (cm)	0.094	1.423	-0.217	-1.578	-0.097	0.169	0.509	-0.369	0.296	0.068	0.056	0.352**
No. of sprouts per bulb	0.272	1.297	-0.465	-1.424	-0.043	0.378	0.835	-0.762	0.084	-0.177	0.112	0.107
Days required for visibility of first spike	0.057	2.672	0.457	-2.949	0.016	-0.102	-3.094	3.319	0.162	-0.132	-0.041	0.366**
Days taken to opening of first flower	0.068	2.863	0.451	-3.160	0.011	-0.087	-3.087	3.326	0.178	-0.163	-0.054	0.346**
No. of florets per spike	0.380	1.559	-0.120	-1.783	-0.054	0.060	-0.944	1.114	0.531	-0.072	0.048	0.719**
Diameter of flower (cm)	0.117	1.111	-0.031	-1.255	0.012	0.119	-0.727	0.965	0.068	-0.561	-0.052	-0.232
No. of spikes per bulb	0.379	0.484	-0.230	-0.525	-0.028	0.218	0.659	-0.924	0.131	0.150	0.194	0.508**

Residual = 0.0355

Table 2: Path coefficient analysis showing the direct and indirect effect of twenty-two characters on the yield of bulb at genotypic level of tuberose

Characters	Diameter of spike (mm)	Length of spike (cm)	Length of rachis (cm)	Longevityof spike	Vase life	No. of bulbs per plant	No. of bulblets per plant	Yield of bulb per plant(gm)	Dia-meter of bulb(mm)	Yield of bulb and bulblets per plant (q/ha)	Yield of bulb (q/ha)
Diameter of spike (mm)	-0.236	0.150	-0.020	-0.040	0.125	-0.030	-0.030	0.126	0.130	0.021	0.197
Length of spike (cm)	-0.200	0.330	-0.080	-0.090	0.006	0.010	-0.040	0.050	0.010	0.001	-0.004
Length of rachis (cm)	-0.070	0.200	-0.130	-0.080	0.045	-0.100	-0.050	0.026	0.060	-0.011	-0.109
Longevity of spike	-0.050	0.080	-0.030	-0.400	0.037	0.090	0.060	0.094	0.020	-0.010	-0.110

Vase life	-0.018	0.060	0.005	0.020	0.114	0.090	0.020	0.006	-0.160	0.017	0.154
No. of bulbs per plant	-0.030	0.084	-0.030	0.080	0.245	-0.126	-0.132	0.211	0.265	0.073	0.640**
No. of bulblets per plant	-0.040	0.040	-0.020	0.125	0.078	-0.044	-0.013	0.345	0.090	0.072	0.634**
Yield of bulb per plant(gm)	-0.090	0.073	0.265	0.040	0.245	-0.031	-0.220	0.452	-0.070	0.127	0.998**
Diameter of bulb(mm)	0.097	-0.020	0.094	0.079	0.026	0.021	0.050	0.163	-0.200	0.037	0.346**
Yield of bulb and bulblets per plant (q/ha)	-0.080	0.000	0.130	0.040	0.044	-0.032	-0.024	0.345	-0.070	0.645	0.998**

Residual = 0.0025

Table 3: Path coefficient analysis showing the direct and indirect effect of twenty-two characters on the yield of bulb at phenotypic level of tuberose.

Characters	Days taken to sprouting	Plant height (cm)	No. of leaves per plant	Length of longest leaf (cm)	Width of longest leaf (cm)	No. of sprouts per bulb	Days required for visibility of first spike	Days taken to opening of first flower	No. of florets per spike	Diameter of flower (cm)	No. of spikes per bulb	Yield of bulb (q/ha)
Days taken to sprouting	0.138	0.165	-0.080	-0.213	0.016	0.026	0.001	-0.001	0.182	-0.014	0.118	0.338**
Plant height (cm)	0.029	0.780	0.046	-0.938	0.016	0.027	0.296	-0.127	0.168	-0.036	0.034	0.295*
No. of leaves per plant	0.049	-0.162	-0.222	0.177	0.018	0.061	-0.283	0.116	0.062	-0.012	0.105	-0.091
Length of longest leaf (cm)	0.031	0.776	0.042	-0.943	0.017	0.026	0.292	-0.126	0.174	-0.037	0.033	0.284*
Width of longest leaf (cm)	0.028	0.152	-0.051	-0.194	0.081	0.025	-0.080	0.025	0.200	0.006	0.084	0.276*
No. of sprouts per bulb	0.034	0.198	-0.130	-0.231	0.020	0.104	-0.121	0.037	0.033	-0.033	0.166	0.078
Days required for visibility of first spike	0.000	0.450	0.123	-0.538	-0.013	-0.025	0.512	-0.204	0.145	-0.034	-0.076	0.341**
Days taken to opening of first flower	0.001	0.442	0.115	-0.532	-0.009	-0.017	0.466	-0.224	0.162	-0.035	-0.086	0.281*
No. of florets per spike	0.048	0.253	-0.027	-0.317	0.031	0.007	0.143	-0.070	0.517	-0.015	0.076	0.647**
Diameter of flower (cm)	0.012	0.166	-0.016	-0.208	-0.003	0.021	0.105	-0.047	0.047	-0.169	-0.070	-0.163
No. of spikes per bulb	0.045	0.075	-0.065	-0.088	0.019	0.048	-0.108	0.054	0.110	0.033	0.360	0.483**

Residual = 0.02932

Table 4: Path coefficient analysis showing the direct and indirect effect of twenty-two characters on the yield of bulb at phenotypic level of tuberose

Characters	Diameter of spike (mm)	Length of spike (cm)	Length of rachis (cm)	Longevity of spike	Vase life	No. of bulbs per plant	No. of bulblets per plant	Yield of bulb per plant (gm)	Diameter of bulb(mm)	Yield of bulb and bulblets per plant (q/ha)	Yield of bulb (q/ha)
Diameter of spike (mm)	-0.023	0.010	-0.005	-0.001	0.010	0.004	0.001	0.162	0.057	-0.032	0.183
Length of spike (cm)	-0.011	0.013	-0.070	-0.003	0.006	0.008	0.073	0.046	0.000	-0.069	-0.008
Length of rachis (cm)	-0.002	0.005	-0.217	-0.004	0.005	0.000	-0.002	0.108	0.000	0.015	-0.092
Longevity of spike	-0.070	0.004	-0.002	-0.048	0.248	0.046	-0.001	-0.243	-0.004	-0.020	-0.090
Vase life	-0.200	0.075	-0.060	0.030	-0.050	0.235	0.110	0.082	-0.001	-0.112	0.116
No. of bulbs per plant	-0.003	0.030	-0.040	0.200	-0.030	0.020	0.312	0.133	0.001	-0.012	0.613**
No. of bulblets per plant	-0.006	0.050	0.003	0.020	0.006	0.200	0.170	0.341	-0.005	-0.173	0.606**
Yield of bulb per plant(gm)	0.001	0.400	0.202	0.095	0.211	0.062	-0.100	0.245	-0.319	-0.043	0.998**

Diameter of bulb(mm)	-0.006	0.070	0.100	0.010	0.060	0.020	0.008	0.213	-0.050	-0.173	0.252*
Yield of bulb and bulblets per plant (q/ha)	-0.017	0.017	-0.053	-0.002	0.073	0.054	0.002	0.144	0.065	0.714	0.997**

Residual = 0.00145

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