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Correlation and path coefficient analysis of yield and yield attributed characters in Brinjal (*Solanum melongena* L.)

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Abstract
The experiment was conducted to evaluate yield and yield attributed characters of 33 brinjal genotypes at College of Horticulture, SKLTSHU, Hyderabad during *Kharif*, 2019 and was laid out in Randomized Block Design with two replications. The correlation coefficient analysis shown fruit yield per plant exhibited maximum positive association with number of fruits per plant (0.8997), marketable yield per plant (0.6300), number of branches per plant (0.2293), fruit diameter (0.1339), fruit weight (0.1233), days to first flowering (0.1176). Path coefficient analysis shown maximum positive direct effect on fruit yield per plant through days to first fruit harvest (1.1811G), number of fruits per plant (0.8929G, 0.9813P), fruit weight (0.7588G, 0.3485P), days to last fruit harvest (0.3340P), days to first flowering (0.2431G) and number of branches per plant (0.2278G). Hence, direct selection can be done by considering these traits as the main criteria to overcome indirect effects for development of high-yielding brinjal varieties.

Keywords: Brinjal, correlation, path coefficient analysis, direct and positive

Introduction
Brinjal (*Solanum melongena* L.; 2n = 24) also known as eggplant or aubergine or guinea squash, is an important crop of sub-tropics and tropics. It belongs to Solanaceae family included under the genus *Solanum*, one of the largest genera covering more than 1550 species. Brinjal is a versatile crop, adapted to different agro-climatic regions and grown throughout the year and throughout the country. It is grown commercially as an annual crop. Major producers are West Bengal, Odisha, Andhra Pradesh, Gujarat, and Bihar. Cultivated varieties are consumed as vegetables, whereas wild and exotic relatives of eggplant are not directly used for human consumption. Brinjal fruits are a fairly good source of calcium, phosphorus, iron and vitamins, particularly vit-B group. Along with tomato and onion it ranks as the second most consumed vegetable in India after potato with 8.3% production share. The fruit of brinjal is very popular among peoples of all social strata and hence, it is rightly called as vegetable of masses (Choudhary and Kalda, 1968) [3]. It is preferred by both vegetarians and non-vegetarians. In India, brinjal occupies an area of 735 thousand ha and production is around 12987 thousand tonnes. (NHB Database, 2018-19) [7].
Improvement in yield and quality is normally achieved by selecting genotypes with desirable character combinations existing in the nature or by hybridization. The natural variation in most of the yield contributing traits of this crop is considerably high and there is need to restructure the variation in the materials for higher yield. Correlation analysis is an important approach in breeding programme. It provides an idea about the degree of various genetic associations between the pairs of character at phenotypic and genotypic level on which selection can be used for genetic improvement in fruit yield. Thus, it only reveals the direction and magnitude of association between any two characters but the path coefficient analysis helps in partitioning genotypic correlation coefficient into direct and indirect effects of various characters on fruit yield or any other attributes. The investigation was therefore, under taken to study the nature and degree of direct and indirect effects of yield and fruit quality contributing characters in collections of brinjal germplasm.

Material and Methods
The present investigation was carried out at PG Research block, Department of Vegetable Science, College of Horticulture, Rajendranagar, SKLTSHU during *Kharif*, 2019. Thirty-three genotypes were laid out in Randomized Block Design with two replications and followed a spacing of 60cm × 60cm.

The experimental material of 33 genotypes were procured from NBPGR, Hyderabad. All recommended package of practices and need based plant protection measures were followed to ensure a good crop. Observations were recorded on five randomly selected plants in each replication for 17 different traits *viz*., plant height (cm), number of branches per plant, days to first flowering, days to 50% flowering, days to first fruit harvest, days to last fruit harvest, plant spread (cm^2), fruit weight (g), fruit length (cm), pedicel length (cm), fruit diameter (mm), number of fruits per plant, marketable yield per plant (kg $plant^{-1}$), fruit yield per plant (kg $plant^{-1}$), test weight (g), ascorbic acid content (mg $100g^{-1}$) and total phenol content (mg $100g^{-1}$). Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958) [2]. Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) [13] and illustrated by Dewey and Lu (1959) [5].

Results and Discussion

Correlation coefficient analysis

The phenotypic (P) and genotypic correlation (G) coefficients were worked out for 17 characters in brinjal and the results are presented in Table 1. 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 major causes underlying association may also be due to pleiotropic gene action or linkage or both.

The results on characters association indicated positive association of fruit yield per plant with plant height (0.0017P, 0.0315G), number of branches per plant (0.2293P, 0.4790G), days to first flowering (0.1176P, 0.1942G), days to first fruit harvest (0.0889P, 0.1454G), days to last fruit harvest (0.0798P, 0.1342G), fruit diameter (0.1339P, 0.1405G), number of fruits per plant (0.8997P, 0.9270G), fruit weight (0.1233P, 0.0724G) and marketable yield per plant (0.6300P, 0.7375G), fruit length (0.0699P, 0.0703G) and total phenol content (0.0406P, 0.0382G) which indicates adequate interrelationship between fruit yield per plant and it's components creating ample scope in the improvement of yield by improving these characters as they are highly correlated. These results were in accordance with the findings of Ahmed *et al.* (2013) [1], Shende *et al.* (2014) [10], Ravali *et al.* (2017) [8], Tiwari *et al.* (2018) [11]. The qualitative character, ascorbic acid content trait indicated positive but non-significant association with plant height (0.1334P, 0.1447G), fruit length (0.2251P, 0.2378G), pedicel length (0.2298P, 0.2468G), fruit weight (0.1242P, 0.1504G) and total phenol content (0.0349P, 0.0387G). Whereas, it exhibited negative non-significant association with the remaining characters and total phenol content exhibited positive non-significant association with number of branches per plant (0.0260P, 0.0526G), days to first flowering (0.1362P, 0.1975G), days to 50% flowering (0.0383P, 0.0274G), days to first fruit harvest (0.0221P, 0.0317G), days to last fruit harvest (0.0182P, 0.0285G), fruit diameter (0.0157P, 0.0072G), number of fruits per plant (0.0411P, 0.0202G) and ascorbic acid content (0.0349P, 0.0387G) and exhibited non-significant negative association with rest of the characters.

On the basis of above results, it is found that the genotypic and phenotypic correlation of number of fruits per plant and marketable yield per plant with the fruit yield per plant was high. Hence, these characters are to be considered as the prior criteria for selection in order to obtain the high yielding varieties of brinjal.

Path coefficient analysis

Path coefficient analysis indicates that the association of the independent character with dependent variable is due to their direct effect on it or is a consequence of their indirect effect through other characters. The path analysis was carried out at phenotypic and genotypic level considering fruit yield per plant (kg $plant^{-1}$) as dependent variable and its attributes *viz*., plant height (cm), number of branches per plant, days to first flowering, days to 50% flowering, days to first fruit harvest, days to last fruit harvest, plant spread (cm^2), fruit weight (g), fruit length (cm), pedicel length (cm), fruit diameter (mm), number of fruits per plant, marketable yield per plant (kg $plant^{-1}$), test weight (g), ascorbic acid content (mg $100g^{-1}$) and total phenol content (mg $100g^{-1}$) as independent variables.

Each component has two paths of action *viz.*, direct influence on fruit yield and indirect effect through component characters which are not revealed from the correlation studies. The estimates of direct and indirect effects of the 16 yield related characters on fruit yield per plant are presented in Table 2. Path coefficient analysis showed that plant height (0.0369G), number of branches per plant (0.2278G, 0.0255P), days to first flowering (0.2431G), days to 50% flowering (0.2200G), days to first fruit harvest (1.1811G), days to last fruit harvest (0.3340P), fruit diameter (0.0392P), number of fruits per plant (0.8929G, 0.9813P), fruit weight (0.7588G, 0.3485P), marketable yield per plant (0.1743G, 0.0306P), test weight (0.0121P), ascorbic acid content (0.0508P) and total phenol content (0.0069P) showed positive direct effect on fruit yield per plant. Similar results were reported in brinjal by Shende *et al.* (2014) [10], Koundinya *et al.* (2017) [6], Ravali *et al.* (2017) [8], Dasmohapatra and Sharma (2018) [4], Sandeep *et al.* (2018) [9], Tripathy *et al.* (2018) [12].It clearly indicates that direct selection based on these characters would be effective for improvement in brinjal.

The residual factor determines how best the causal factors account for the variability of the dependent factor, the fresh fruit yield per plant in this case. The residual effects were 0.194 and 1.040 which is of low magnitude at phenotypic and genotypic levels respectively.

Table 1: Phenotypic (P) and genotypic (G) correlation coefficients among yield and yield attributes in 33 genotypes of Brinjal

Character		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Days to first fruit harvest	Days to last fruit harvest	Plant spread (cm^2)	Fruit length (cm)	Fruit diameter (mm)	Pedicel length (cm)	No. of fruits per plant	Fruit weight (g)	Marketable yield per plant (kg $plant^{-1}$)	Test weight (g)	Ascorbic acid content (mg $100g^{-1}$)	Total phenol content (mg $100g^{-1}$)	Yield per plant (kg $plant^{-1}$)
Plant height(cm)	P	1.0000	0.0303	-0.2613*	-0.0687	-0.0588	-0.0611	0.2932*	0.3018*	0.0004	0.3709**	-0.0616	0.1918	0.1567	-0.0224	0.1334	-0.1657	0.0017
	G	1.0000	0.0407	-0.4475	-0.1015	-0.0676	-0.0767	0.2992	0.3204	0.0107	0.3867	-0.0454	0.2036	0.1770	-0.0231	0.1447	-0.1614	0.0315
No. of branches per plant	P		1.0000	0.0005	-0.1381	0.1016	0.1026	0.3773**	0.0520	-0.0447	-0.0693	0.2417	-0.1569	0.4316***	0.0620	-0.0907	0.0260	0.2293
	G		1.0000	-0.2842	-0.2337	-0.1644	-0.1516	0.5229	0.0674	-0.0205	-0.0568	0.5440	-0.3426	0.8142	0.0782	-0.1131	0.0526	0.4790
Days to first flowering	P			1.0000	0.5095***	0.8210***	0.8251***	-0.2122	-0.0351	-0.1205	-0.1287	0.1874	-0.0097	-0.0945	0.0555	-0.1566	0.1362	0.1176
	G			1.0000	0.9397	0.8175	0.8114	-0.3868	-0.1077	-0.1157	-0.1919	0.2903	-0.1769	-0.2054	0.1141	-0.2916	0.1975	0.1942
Days to 50% flowering	P				1.0000	0.5780***	0.5783***	-0.2167	-0.1555	-0.0113	-0.0986	-0.0125	-0.0014	-0.2062	0.2251	-0.1391	0.0383	-0.1162
	G				1.0000	0.9377	0.9413	-0.2308	-0.1698	-0.0019	-0.1120	0.0147	-0.0062	-0.3063	0.2460	-0.1613	0.0274	-0.0662
Days to first fruit harvest	P					1.0000	0.9987***	-0.0432	-0.0023	-0.1172	-0.0712	0.1511	0.0224	-0.0246	0.0941	-0.2183	0.0221	0.0889
	G					1.0000	1.0007	-0.0674	-0.0501	-0.1383	-0.0715	0.2609	-0.0854	-0.0476	0.1448	-0.3657	0.0317	0.1454
Days to last fruit harvest	P						1.0000	-0.0460	0.0008	-0.1255	-0.0668	0.1442	0.0159	-0.0344	0.1009	-0.2197	0.0182	0.0798
	G						1.0000	-0.0719	-0.0466	-0.1428	-0.0657	0.2555	-0.0970	-0.0608	0.1552	-0.3632	0.0285	0.1342
Plant spread (cm^2)	P							1.0000	0.0527	-0.0467	0.0370	-0.0180	-0.0012	0.2416	-0.2018	-0.0723	-0.0005	0.0002
	G							1.0000	0.0536	-0.0499	0.0381	-0.0204	-0.0015	0.2808	-0.2020	-0.0733	-0.0005	-0.0001
Fruit length (cm)	P								1.0000	-0.6223***	0.0230	0.2026	-0.3271**	-0.0518	-0.2341	0.2251	-0.1766	0.0699
	G								1.0000	-0.6799	0.0258	0.2292	-0.4165	-0.0837	-0.2386	0.2378	-0.1790	0.0703

Table 1: (Contd…)

Character		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Days to first fruit harvest	Days to last fruit harvest	Plant spread (cm^2)	Fruit length (cm)	Fruit diameter (mm)	Pedicel length (cm)	No. of fruits per plant	Fruit weight (g)	Marketable yield per plant (kg $plant^{-1}$)	Test weight (g)	Ascorbic acid content (mg $100g^{-1}$)	Total phenol content (mg $100g^{-1}$)	Yield per plant (kg $plant^{-1}$)
Fruit diameter (mm)	P									1.0000	0.1596	-0.1477	0.6558***	0.3201**	0.2765*	-0.0137	0.0157	0.1339
	G									1.0000	0.1735	-0.1941	0.8298	0.3901	0.2976	-0.0249	0.0072	0.1405
Pedicel length (cm)	P										1.0000	-0.1054	0.1915	0.0820	0.2897*	0.2296	-0.2280	-0.0532
	G										1.0000	-0.1241	0.2867	0.1159	0.2948	0.2468	-0.2354	-0.0477
No. of fruits per plant	P											1.0000	-0.2588*	0.5234***	-0.1712	-0.1142	0.0411	0.8997
	G											1.0000	-0.3121	0.5305	-0.1879	-0.1410	0.0202	0.9270
Fruit weight (g)	P												1.0000	0.1573	0.2640*	0.1242	-0.0302	0.1233
	G												1.0000	0.2145	0.3156	0.1504	-0.0242	0.0724
Marketable yield per plant (kg $plant^{-1}$)	P													1.0000	-0.0279	-0.0744	-0.0614	0.6300
	G													1.0000	-0.0313	-0.1110	-0.0964	0.7375
Test weight (g)	P														1.0000	-0.2024	-02094	-0.0918
	G														1.0000	-0.2033	-0.2106	-0.0997
Ascorbic acid content (mg $100g^{-1}$)	P															1.0000	0.0349	-0.0257
	G															1.0000	0.0387	-0.0411
Total phenol	P																1.0000	0.0406

content (mg $100g^{-1}$)	G																1.0000	0.0382

Significance at 0.01 level
** Significance at 0.05 level
***Significance at 0.001 level

Table 2: Direct and indirect effects of various yield attributes on fruit yield in 33 genotypes of Brinjal

Character		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Days to first fruit harvest	Days to last fruit harvest	Plant spread (cm^2)	Fruit length (cm)	Fruit diameter (mm)	Pedicel length (cm)	No. of fruits per plant	Fruit weight (g)	Marketable yield per plant (kg $plant^{-1}$)	Test weight (g)	Ascorbic acid content (mg $100g^{-1}$)	Total phenol content (mg $100g^{-1}$)	Yield per plant (kg $plant^{-1}$)
Plant height (cm)	P	-0.0022	-0.0001	0.0006	0.0001	0.0001	0.0001	-0.0006	-0.0006	0.0000	-0.0008	0.0001	-0.0004	-0.0003	0.0000	-0.0003	0.0004	0.0017
	G	0.0369	0.0015	-0.0165	-0.0038	-0.0025	-0.0028	0.0111	0.0118	0.0004	0.0143	-0.0017	0.0075	0.0065	-0.0009	0.0053	-0.0060	0.0315
No. of branches per plant	P	0.0008	0.0255	0.0000	-0.0035	0.0026	0.0026	0.0096	0.0013	-0.0011	-0.0018	0.0062	-0.0040	0.0110	0.0016	-0.0023	0.0007	0.2293
	G	0.0093	0.2278	-0.0647	-0.0532	-0.0374	-0.0345	0.1191	0.0153	-0.0047	-0.0129	0.1239	-0.0780	0.1854	0.0178	-0.0258	0.0120	0.4790
Days to first flowering	P	0.0072	0.0000	-0.0275	-0.0140	-0.0226	-0.0227	0.0058	0.0010	0.0033	0.0035	-0.0052	0.0003	0.0026	-0.0015	0.0043	-0.0037	0.1176
	G	-0.1088	-0.0691	0.2431	0.2284	0.1987	0.1972	-0.0940	-0.0262	-0.0281	-0.0466	0.0706	-0.0430	-0.0499	0.0277	-0.0709	0.0480	0.1942
Days to 50% flowering	P	0.0066	0.0133	-0.0490	-0.0962	-0.0556	-0.0556	0.0208	0.0150	0.0011	0.0095	0.0012	0.0001	0.0198	-0.0217	0.0134	-0.0037	-0.1162
	G	-0.0223	-0.0514	0.2067	0.2200	0.2063	0.2071	-0.0508	-0.0373	-0.0004	-0.0246	0.0032	-0.0014	-0.0674	0.0541	-0.0355	0.0060	-0.0662
Days to first fruit harvest	P	0.0185	-0.0139	-0.2579	-0.1816	-0.3141	-0.3137	0.0136	0.0007	0.0368	0.0224	-0.0475	-0.0071	0.0077	-0.0296	0.0686	-0.0069	0.0889
	G	-0.0799	-0.1942	0.9656	1.1076	1.1811	1.1819	-0.0796	-0.0591	-0.1634	-0.0845	0.3082	-0.1009	-0.0562	0.1710	-0.4319	0.0374	0.1454
Days to last fruit harvest	P	-0.0204	0.0342	0.2756	0.1931	0.3335	0.3340	-0.0154	0.0003	-0.0419	-0.0223	0.0482	0.0053	-0.0115	0.0337	-0.0734	0.0061	0.0798
	G	0.1261	0.2492	-1.3337	-1.5471	-1.6448	-1.6437	0.1182	0.0766	0.2347	0.1080	-0.4199	0.1595	0.0999	-0.2551	0.5969	-0.0468	0.1342
Plant spread (cm^2)	P	-0.0037	-0.0048	0.0027	0.0027	0.0005	0.0006	-0.0126	-0.0007	0.0006	-0.0005	0.0002	0.0000	-0.0031	0.0026	0.0009	0.0000	0.0002
	G	-0.0289	-0.0505	0.0373	0.0223	0.0065	0.0069	-0.0965	-0.0052	0.0048	-0.0037	0.0020	0.0001	-0.0271	0.0195	0.0071	0.0000	-0.0001
Fruit length(cm)	P	-0.0036	-0.0006	0.0004	0.0019	0.0000	0.0000	-0.0006	-0.0121	0.0075	-0.0003	-0.0024	0.0040	0.0006	0.0028	-0.0027	0.0021	0.0699
	G	-0.0400	-0.0084	0.0135	0.0212	0.0063	0.0058	-0.0067	-0.1249	0.0849	-0.0032	-0.0286	0.0520	0.0105	0.0298	-0.0297	0.0223	0.0703

Table 2: (Contd…)

Character		Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Days to first fruit harvest	Days to last fruit harvest	Plant spread (cm^2)	Fruit length (cm)	Fruit diameter (mm)	Pedicel length (cm)	No. of fruits per plant	Fruit weight (g)	Marketable yield per plant (kg $plant^{-1}$)	Test weight (g)	Ascorbic acid content (mg $100g^{-1}$)	Total phenol content (mg $100g^{-1}$)	Yield per plant (kg $plant^{-1}$)
Fruit diameter(mm)	P	0.0000	-0.0018	-0.0047	-0.0004	-0.0046	-0.0049	-0.0018	-0.0244	0.0392	0.0063	-0.0058	0.0257	0.0125	0.0108	-0.0005	0.0006	0.1339
	G	-0.0052	0.0099	0.0557	0.0009	0.0666	0.0688	0.0240	0.3276	-0.4818	-0.0836	0.0935	-0.3998	-0.1880	-0.1434	0.0120	-0.0035	0.1405
Pedicel length (cm)	P	-0.0180	0.0034	0.0063	0.0048	0.0035	0.0032	-0.0018	-0.0011	-0.0078	-0.0486	0.0051	-0.0093	-0.0040	-0.0141	-0.0112	0.0111	-0.0532
	G	-0.0002	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001	-0.0006	0.0001	-0.0002	-0.0001	-0.0002	-0.0001	0.0001	-0.0477
No. of fruits per plant	P	-0.0605	0.2372	0.1839	-0.0123	0.1482	0.1415	-0.0176	0.1988	-0.1450	-0.1035	0.9813	-0.2539	0.5136	-0.1680	-0.1121	0.0404	0.8997
	G	-0.0406	0.4857	0.2593	0.0131	0.2330	0.2281	-0.0182	0.2047	-0.1733	-0.1108	0.8929	-0.2787	0.4737	-0.1678	-0.1259	0.0180	0.9270
Fruit weight (g)	P	0.0669	-0.0547	-0.0034	-0.0005	0.0078	0.0056	-0.0004	-0.1140	0.2285	0.0667	-0.0902	0.3485	0.0548	0.0920	0.0433	-0.0105	0.1233
	G	0.1545	-0.2600	-0.1342	-0.0047	-0.0648	-0.0736	-0.0011	-0.3160	0.6296	0.2175	-0.2368	0.7588	0.1628	0.2395	0.1141	-0.0183	0.0724
Marketable yield per plant (kg $plant^{-1}$)	P	0.0048	0.0132	-0.0029	-0.0063	-0.0008	-0.0011	0.0074	-0.0016	0.0098	0.0025	0.0160	0.0048	0.0306	-0.0009	-0.0023	-0.0019	0.6300
	G	0.0309	0.1419	-0.0358	-0.0534	-0.0083	-0.0106	0.0490	-0.0146	0.0680	0.0202	0.0925	0.0374	0.1743	-0.0055	-0.0193	-0.0168	0.7375
Test weight (g)	P	-0.0003	0.0008	0.0007	0.0027	0.0011	0.0012	-0.0025	-0.0028	0.0034	0.0035	-0.0021	0.0032	-0.0003	0.0121	-0.0025	-0.0025	-0.0918
	G	0.0024	-0.0082	-0.0120	-0.0259	-0.0152	-0.0163	0.0213	0.0251	-0.0313	-0.0310	0.0198	-0.0332	0.0033	-0.1052	0.0214	0.0222	-0.0997
Ascorbic acid content (mg $100g^{-1}$)	P	0.0068	-0.0046	-0.0080	-0.0071	-0.0111	-0.0112	-0.0037	0.0114	-0.0007	0.0117	-0.0058	0.0063	-0.0038	-0.0103	0.0508	0.0018	-0.0257
	G	-0.0083	0.0065	0.0168	0.0093	0.0210	0.0209	0.0042	-0.0137	0.0014	-0.0142	0.0081	-0.0087	0.0064	0.0177	-0.0575	-0.0022	-0.0411
Total phenol content (mg $100g^{-1}$)	P	-0.0011	0.0002	0.0009	0.0003	0.0002	0.0001	0.0000	-0.0012	0.0001	-0.0016	0.0003	-0.0002	-0.0004	-0.0014	0.0002	0.0069	0.0406
	G	0.0055	-0.0018	-0.0068	-0.0009	-0.0011	-0.0010	0.0000	0.0061	-0.0002	0.0081	-0.0007	0.0008	0.0033	0.0072	-0.0013	-0.0343	0.0382

Diagonal (under lined) values indicate direct effects

Conclusion

It is concluded that the results obtained from the study regarding the character associations and their direct and indirect effects of the traits will further help to obtain the appropriate desirable characters along with enhanced fruit yields of brinjal. From this study, it is identified that the great emphasis on the traits *viz*., plant height, number of branches per plant, days to first flowering, days to first fruit harvest, days to last fruit harvest, fruit diameter, number of fruits per plant, fruit weight, marketable yield per plant and total phenol content would greatly results in higher yields of brinjal genotypes. There is a need to further test under different agricultural conditions and those which found suitable can be recommended for general cultivation and also the respective genotypes can be utilized for future breeding programmes.

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