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Interrelationship of genetics parameters for quantitative and physiological traits in rice under irrigated and drought conditions

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ABSTRACT

High estimates of heritability, genetic advance, genotypic and phenotypic coefficients of variation (GCV and PCV) recorded for apparent contribution rate (h^2:98.79, Ga 92.23, PCV: 50.23 and GCV: 49.93) under irrigated condition while, apparent contribution rate, grain yield plant^{-1} and biological yield plant^{-1} under drought condition emerged as ideal traits for improvement through selection procedures. Grains panicle^{-1}, spikelet fertility and membrane thermo stability with high heritability and genetic advance and moderate GCV and PCV appear as good indices for selection under stress condition. The very strong positive association of grain yield plant^{-1} was observed at both levels with biological yield plant^{-1} (r_p=0.963, r_g=0.997 in irrigated and r_p=0.906, r_g=0.946 in drought condition) under both the conditions followed by harvest index (r_p=0.592, r_g=0.613). Path-coefficient analysis identified biological yield plant^{-1}, harvest index and grains panicle^{-1} as most important direct yield component while, biological yield plant^{-1} emerged as most important indirect yield component under irrigated condition. In drought condition, biological yield plant^{-1} was found to be most important direct yield contributor and harvest index, grains panicle^{-1}, spikelets panicle^{-1}, spikelet fertility, plant height and apparent contribution rate as direct components of secondary importance, while biological yield plant^{-1} was most important indirect yield attribute.

Key words: *rice, physiological traits, heritability, genetic advance, path analysis*

Drought is an important production constraint of rice in eastern India, with more than 10 million ha of drought prone land, where yield losses due to drought are reported to cost an average of US $250 million annually (Bernier *et al.,* 2008). The direct selection parameters help us in developing suitable selection strategy for enhancing the effectiveness and efficiency of selection in improving plant characters. The results of character association studies in rice by earlier workers have been found to be non-consistent varying with the materials and environment used (Mahto *et al*., 2003 and Babar *et al*., 2009). Further probe in this respect in rice might prove useful due to non-consistent findings reported earlier. Hence, an attempt was made to assess and compare direct selection parameters and interrelationship between sixteen characters and variability under irrigated and drought conditions.

In the present study, six generations (P_1, P_2, F_1, F_2, B_1, B_2) of six crosses *viz.*, Sarjoo 52 x P0 359, P0 359 x Sonam, NDR 359 x P0 1564, P0 1564 x Sarjoo 52, IR 74409 x Saita, DSL 63-8 x NDR-359 were evaluated in compact family block design with three replications under irrigated and drought conditions during wet season of 2006 at N. D. University of Agriculture and Technology, Faizabad, Uttar Pradesh. The rows of 3 m length were used for making sub-plots of two rows for P_1, P_2 and F_{-1} generations, 4 rows for B_1 and B_2 generations and 6 rows for F_2 generations of each cross at 20 x 15 cm spacing. The experimental field was left uncovered to receive natural rainfall in irrigated condition. In addition to this, experimental plots were irrigated to maintain appropriate moisture levels as recommended for irrigated rice. While, the experimental field was covered by constructing temporary shelter at a height of 3.5 meter fetes using polythene sheets to exclude any possibility of natural rain falling in the experimental plots. Care was taken to check the inflow or seepage of water from the adjoining areas by making adequate bunds around the experimental plots representing in drought condition.

Drought at flowering stage was created by with holding the irrigation one week before panicle exertion and exposed for two weeks (60-80 KPa.). Drought was released by irrigation. The characters studied in the two experiments were days to 50 per cent flowering, size of flag leaf excluding sheath, plant height, ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1}, spikelets panicle^{-1}, spikelet fertility, test weight, grain yield plant^{-1}, biological yield plant^{-1}, harvest-index, relative water content, membrane thermo stability, apparent translocation rate and apparent contribution rate. The data were analyzed by appropriate statistical analysis (Gomez and Gomez, 1984) using CropStat 7.2 (IRRI, 2009) programme. The genetic parameters, correlation coefficients and path coefficient at genotypic and phenotypic levels were computed following Singh and Chaudhury (1985).

Analysis of variance revealed significant differences among the six cross families as well as their progenies for all the characters under both the conditions with a few exceptions. Grain yield plant^{-1} and biological yield plant^{-1} under drought were the only traits which possessed very high estimates of phenotypic and genotypic coefficient of variation (PCV and GCV), heritability (h^2b) and genetic advance ($\overline{Ga}$) while, apparent translocation rate, spikelets panicle^{-1}, grains panicle^{-1} and size of flag leaf excluding sheath under irrigated and grains panicle^{-1}, spikelet fertility, and membrane thermo stability under drought exhibited moderate estimates (Table 1). Thus, these characters emerged as ideal traits for improvement through selection owing to their transmissibility and variability under irrigated and drought condition. Similar results were also reported earlier for grains panicle^{-1} and spikelets panicle^{-1} by Suman *et al*. (2005); size of flag leaf excluding sheath by Manna *et al*. (2006) and Haung (1984) found moderate heritability for spikelet fertility. The four characters *viz*., days to 50 per cent flowering, test weight, harvest index and relative water content exhibited low estimates of all the four parameters (h^2b, , PCV and GCV) except moderate heritability recorded for days to 50 per cent flowering, test weight and relative water content.

The very strong positive association of grain yield plant^{-1} was observed at both levels with biological yield plant^{-1} (r_p=0.963, r_g=0.997 in irrigated and r_p=0.906, r_g=0.946 in drought condition) under both the conditions followed by harvest index (r_p=0.592, r_g=0.613), test weight (r_p=0.377, r_g=0.592), panicle length (r_p=0.392, r_g=0.578) and apparent translocation rate (r_p=0.433, r_g=0.562) under irrigated condition and spikelets panicle^{-1} (r_p=0.651, r_g=0.722), grains panicle^{-1} (r_p=0.553, r_g=0.573) and harvest index (r_p=0.262, r_g=0.325) under drought condition. The above mentioned characters with exception to apparent translocation rate have also been found to exhibit strong positive association with grain yield plant^{-1} (Janardanam *et al*., 2002 and Mahto *et al*., 2003). The apparent translocation rate exhibited strong positive genotypic and phenotypic correlations with membrane thermo stability, relative water content and biological yield plant^{-1} under irrigated condition. The strong positive association of days to 50 per cent flowering with membrane thermo stability and ear bearing tillers plant^{-1}; relative water content with plant height and apparent translocation rate and apparent contribution rate with panicle length were also noted at both the levels under drought condition. Theses results are in agreement with those of previous workers (Chandra and Das, 2000; Shivani and Reddy, 2000; Mahto *et al*., 2003 and Babar *et al*., 2009). In the present study, it appeared that drought condition brought increase in degree of character associations as compared to irrigated condition with similar nature between different characters at both the levels. However, the genotypic correlations were slightly greater in magnitude than their corresponding phenotypic correlations. Similar results have also been reported in rice by Shivani and Reddy (2000).

Biological yield plant^{-1} followed by harvest index and grains panicle^{-1} exerted very high order positive direct effects on grain yield plant^{-1} at both the levels under irrigated condition while, biological yield plant^{-1} showed substantial positive direct effect at both the levels and harvest index and grains panicle^{-1} showed positive direct effects only at genotypic level under drought condition (Table 2 and 3). Therefore, biological yield plant^{-1}, harvest index and grains panicle^{-1} emerged as most important direct contributors of grain yield plant^{-1} for both the conditions (Venkataramana and Hittalmani, 2000 and Mishra and Verma, 2002). Considerable positive direct effects of relative water content and apparent contribution rate at genotypic level were also noted under both the conditions and considered as direct yield components of secondary

Table 1. Direct selection parameters for 16 metric traits in rice under irrigated and drought conditions

Characters	Conditions	Grand mean(m)	Coefficient of variation			Heritability (h^2b)	Genetic advance as per cent of mean
			PCV	GCV	ECV		
DFF	Irrigated	93.69	6.24	5.24	3.40	70.36	9.05
	Drought	97.83	6.26	4.10	3.78	63.55	8.20
SFL	Irrigated	35.92	14.05	12.48	6.45	78.95	22.851
	Drought	31.11	8.24	6.43	5.16	60.84	10.33
PH	Irrigated	107.31	13.59	11.70	6.90	74.21	20.77
	Drought	92.00	10.29	9.52	3.91	85.57	18.13
EBT	Irrigated	7.40	11.57	9.61	6.44	68.99	16.45
	Drought	5.76	10.55	9.89	3.68	87.85	19.10
PL	Irrigated	24.31	14.46	12.35	7.52	72.96	21.74
	Drought	21.36	8.08	6.23	5.15	59.43	9.90
G/P	Irrigated	94.87	13.67	12.13	6.31	78.67	22.16
	Drought	59.08	15.23	14.53	4.55	91.07	28.57
S/P	Irrigated	113.02	13.28	11.96	5.77	81.14	22.20
	Drought	95.59	9.76	8.80	4.23	81.26	16.34
SF	Irrigated	84.04	6.16	1.07	6.06	3.02	38.34
	Drought	61.80	11.57	10.67	4.49	84.96	20.25
TW	Irrigated	21.48	7.36	5.91	4.41	64.24	9.75
	Drought	18.97	10.52	9.55	4.42	82.37	17.86
GY/P	Irrigated	19.64	22.98	9.39	8.96	52.37	14.00
	Drought	8.77	30.08	29.02	7.92	93.07	57.68
BY/P	Irrigated	45.24	11.17	8.63	7.09	59.74	13.75
	Drought	25.66	27.59	27.15	4.88	96.87	55.06
HI	Irrigated	43.33	3.73	2.20	4.06	34.90	2.68
	Drought	34.28	11.93	8.11	8.75	46.21	11.35
RWC	Irrigated	77.53	5.26	4.09	3.32	60.31	6.54
	Drought	66.18	7.66	7.07	2.94	85.25	13.45
MTS	Irrigated	38.16	6.68	5.80	3.32	75.31	10.37
	Drought	48.89	13.55	13.20	3.03	94.97	26.50
ATR	Irrigated	0.12	16.10	15.35	7.29	81.59	28.57
	Drought	0.30	8.69	7.70	4.03	78.52	14.06
ACR	Irrigated	0.17	50.23	49.93	5.53	98.79	102.23
	Drought	0.23	36.22	35.58	6.80	96.47	71.98

DFF: days to 50 per cent flowering; SFL: size of flag leaf excluding sheath; PH: plant height; EBT: ear bearing tillers plant^{-1}; PL: panicle length; G/P: grains panicle^{-1}; S/P: spikelets panicle^{-1}; SF: spikelet fertility; TW: test-weight; GY/P: grain yield plant^{-1}; BY/P: biological yield plant^{-1}; HI: harvest-index; RWC: relative water content; MTS: membrane thermo stability; ATR: apparent translocation rate and ACR: apparent contribution rate

importance. In case of indirect effects, biological yield plant^{-1} exhibited substantial positive indirect effects on grain yield plant^{-1} at phenotypic level *via* spikelets panicle^{-1} and grains panicle^{-1} under irrigated and at both the levels under drought condition. Thus, biological yield plant^{-1} was identified as most important indirect yield component for both the conditions. The estimates of residual factors were also very low in the path analyses carried out at both the levels under both the conditions.

The present studies suggest that the genotype x environment interactions also play substantial role in conditioning the nature and degree of character

Table 2. Direct and indirect effects of 15 characters on grain yield plant^{-1} at phenotypic and genotypic levels in rice under irrigated condition

Characters		DFF	SFL	PH	EBT	PL	G/P	S/P	SF	TW	BY/P	HI	RWC	MTS	ATR	ACR	Correlation with grain yield plant^{-1}
DFF	P	**0.006**	0.002	0.002	0.002	0.001	0.002	0.002	0.000	0.000	0.001	0.001	0.002	0.001	0.002	0.000	-0.105
	G	**0.778**	-0.399	0.171	0.220	-0.359	0.185	0.246	-0.736	-0.244	-0.218	0.036	-0.580	-0.394	-0.432	-0.061	-0.268
SFL	P	-0.002	**0.008**	0.001	0.004	0.005	-0.002	-0.002	0.001	0.004	0.002	0.001	0.000	0.001	0.002	0.001	0.228*
	G	0.200	**-0.391**	-0.038	-0.227	-0.305	0.140	0.158	-0.180	-0.198	-0.103	0.059	0.034	-0.051	-0.118	-0.063	0.275
PH	P	-0.003	-0.001	**-0.011**	-0.005	0.001	0.001	0.000	0,0008	-0.002	0.001	0.000	0.000	-0.004	0.000	-0.007	-0.085
	G	0.036	0.016	**0.162**	0.100	-0.037	-0.020	-0.017	-0.044	0.027	-0.028	0.016	-0.028	0.060	0.001	0.118	-0.181
EBT	P	0.001	0.001	0.001	**0.002**	0.000	0.000	0.000	0.000	0.001	0.000	0.000	-0.001	0.000	0.000	0.000	-0.021
	G	-0.149	-0.305	-0.322	**-0.526**	-0.111	0.057	0.055	0.037	-0.160	0.072	0.006	0.384	0.148	0.152	-0.176	-0.125
PL	P	0.003	-0.009	0.001	-0.003	**-0.013**	0.003	0.003	0.001	0.005	0.005	0.001	0.004	0.004	0.006	0.002	0.364**
	G	-0.786	1.330	-0.390	0.359	**1.705**	-0.510	-0.691	1.959	0.650	0.943	-0.502	0.349	0.538	0.844	-0.354	0.578
G/P	P	0.042	-0.035	-0.006	0.000	-0.028	**0.141**	0.127	0.041	0.038	0.029	0.008	0.010	-0.039	-0.017	-0.019	0.193*
	G	0.806	-1.217	-0.415	-0.370	-1.017	**3.398**	3.396	0.683	0.762	0.861	-0.465	-0.249	-1.745	-0.694	-0.536	0.268
S/P	P	-0.045	0.040	0.002	-0.002	0.034	0.123	**0.137**	0.022	0.024	0.019	0.004	0.007	0.046	0.018	0.023	0.132
	G	-1.056	1.345	0.349	0.348	1.352	-3.335	**-3.336**	-0.503	-0.402	-0.283	0.172	0.457	1.906	0.775	0.668	0.094
SF	P	0.004	-0.005	0.005	0.002	-0.006	-0.018	0.010	**0.063**	0.015	0.010	0.003	0.004	0.006	0.002	0.004	0.145
	G	0.317	-0.154	0.091	0.024	-0.385	-0.068	-0.051	**-0.335**	-0.430	-0.642	0.352	-0.261	-0.185	-0.100	-0.158	1.997
TW	P	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.001	**0.004**	0.002	0.000	0.001	0.001	0.000	0.001	0.377**
	G	-0.087	0.140	0.046	0.084	0.106	0.062	0.033	0.356	**0.278**	0.154	-0.090	-0.001	-0.012	0.014	0.067	0.592
BY/P	P	-0.074	0.211	-0.080	0.002	0.337	0.175	0.122	0.133	0.357	**0.860**	0.308	0.271	0.107	0.324	-0.048	0.963**
	G	-0.097	0.091	-0.060	-0.047	0.192	0.088	0.029	0.663	0.193	**0.346**	-0.170	0.115	0.006	0.144	-0.029	1.034
HI	P	-0.033	0.016	-0.002	-0.022	0.030	0.016	0.009	0.012	0.019	0.102	**0.285**	0.007	0.001	0.026	-0.011	0.592**
	G	0.026	-0.083	0.056	-0.006	-0.163	-0.076	-0.029	-0.580	-0.180	-0.271	**0.553**	-0.147	-0.026	-0.125	0.012	-0.218
RWC	P	0.001	0.000	0.000	0.001	-0.001	0.000	0.000	0.000	0.000	-0.001	0.000	**-0.002**	-0.001	-0.001	0.000	0.278**
	G	-0.792	-0.092	-0.186	-0.775	0.218	-0.078	-0.146	0.827	-0.002	0.352	-0.282	**1.063**	0.538	0.633	-0.150	0.366
MTS	P	0.000	0.000	0.001	0.000	0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	0.001	**0.002**	0.001	0.001	0.108
	G	0.561	-0.145	-0.407	0.311	-0.349	0.569	0.633	-0.611	0.048	-0.018	0.053	-0.560	**-1.107**	-0.766	-0.449	0.027
ATR	P	-0.003	0.003	0.000	-0.002	0.004	-0.001	-0.001	0.000	0.001	0.003	0.001	0.005	0.005	**0.009**	0.002	0.353**
	G	0.057	-0.031	-0.001	0.030	-0.051	0.021	0.024	-0.031	-0.005	-0.043	0.023	-0.061	-0.071	**-0.103**	-0.021	0.433
ACR	P	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	**0.002**	-0.058
	G	-0.083	0.169	0.763	0.351	-0.218	-0.166	-0.210	0.493	0.255	-0.088	0.023	-0.149	0.426	0.209	**1.050**	-0.080

Residual factors = 0.037 and Bold figures indicate direct effects

DFF: days to 50 per cent flowering; SFL: size of flag leaf excluding sheath; PH: plant height; EBT: ear bearing tillers plant^{-1}; PL: panicle length; G/P: grains panicle^{-1}; S/P: spikelets panicle^{-1}; SF: spikelet fertility; TW: test-weight; BY/P: biological yield plant^{-1}; HI: harvest-index; RWC: relative water content; MTS: membrane thermo stability; ATR: apparent translocation rate and ACR: apparent contribution rate

Table 3. Direct and indirect effects of 15 characters on grain yield plant^{-1} at phenotypic and genotypic levels in rice under drought condition

Characters		DFF	SFL	PH	EBT	PL	G/P	S/P	SF	TW	BY/P	HI	RWC	MTS	ATR	ACR	Correlation with grain yield plant^{-1}
DFF	P	**-0.033**	0.002	-0.010	-0.012	0.001	-0.008	-0.011	-0.002	-0.015	0.003	-0.008	0.006	-0.017	0.007	0.006	-0.005
	G	**-0.101**	0.039	-0.027	-0.036	0.031	-0.024	-0.023	-0.014	-0.043	0.016	-0.039	0.044	-0.054	0.051	0.025	-0.073
SFL	P	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022
	G	0.026	**-0.068**	-0.008	0.003	-0.021	-0.004	0.016	-0.018	-0.002	-0.009	0.034	-0.001	0.000	-0.009	0.011	-0.032
PH	P	-0.001	-0.001	**-0.005**	-0.001	0.000	-0.002	0.000	-0.003	-0.003	-0.001	-0.001	-0.002	0.000	-0.001	0.003	0.266**
	G	0.113	0.051	**0.424**	0.063	-0.095	0.199	0.004	0.278	0.258	0.088	0.148	0.129	-0.050	0.074	-0.299	0.275
EBT	P	0.006	0.000	0.003	**0.016**	0.003	0.008	0.006	0.005	0.008	-0.002	0.004	-0.005	0.007	-0.007	-0.002	-0.022
	G	0.022	-0.003	0.009	**0.061**	0.006	0.033	0.023	0.026	0.033	-0.010	0.024	-0.031	0.028	-0.039	-0.009	-0.047
PL	P	0.001	-0.012	0.002	-0.008	**-0.044**	-0.005	-0.010	0.002	-0.016	-0.003	-0.005	-0.014	0.010	-0.003	-0.018	0.083
	G	0.021	-0.021	0.015	-0.007	**-0.069**	-0.004	-0.007	0.001	-0.022	-0.002	-0.008	-0.014	0.028	0.005	-0.033	0.042
G/P	P	0.064	0.020	0.118	0.132	0.027	**0.253**	0.169	0.190	0.139	0.119	0.064	-0.002	0.032	0.000	-0.050	0.553**
	G	-0.406	-0.094	-0.802	-0.905	-0.094	**-1.704**	-1.201	-1.334	-1.001	-0.830	-0.585	0.136	-0.160	0.121	0.372	0.573
S/P	P	-0.038	0.010	-0.011	-0.047	-0.027	-0.079	**-0.117**	-0.002	-0.040	-0.063	-0.035	0.014	-0.021	0.000	-0.015	0.651**
	G	0.272	-0.277	0.012	0.436	0.120	0.832	**1.180**	0.131	0.370	0.674	0.614	-0.310	0.153	-0.155	0.141	0.722
SF (%)	P	-0.011	-0.033	-0.110	-0.068	0.009	-0.148	-0.003	**-0.197**	-0.088	-0.030	-0.015	-0.019	-0.003	0.000	0.075	0.164
	G	0.151	0.285	0.719	0.458	-0.011	0.857	0.122	**1.094**	0.610	0.195	0.039	0.135	0.018	0.008	-0.455	0.169
TW	P	0.002	0.000	0.002	0.002	0.001	0.002	0.001	0.002	**0.003**	0.000	0.001	0.001	0.000	0.000	-0.001	0.180
	G	0.010	0.001	0.015	0.013	0.008	0.014	0.008	0.014	**0.025**	0.002	0.010	0.005	-0.002	-0.004	-0.007	0.175
BY/P	P	-0.084	0.117	0.204	-0.120	0.053	0.434	0.495	0.142	0.084	**0.924**	-0.087	0.060	-0.082	0.251	-0.182	0.906**
	G	-0.140	0.120	0.180	-0.146	0.020	0.421	0.494	0.154	0.070	**0.866**	-0.054	0.033	-0.094	0.237	-0.183	0.946
HI (%)	P	0.094	-0.083	0.072	0.095	0.043	0.102	0.121	0.031	0.103	-0.038	**0.400**	0.051	-0.030	0.000	0.053	0.325**
	G	0.016	-0.020	0.014	0.016	0.005	0.014	0.021	0.001	0.016	-0.003	**0.040**	0.008	-0.006	0.006	0.009	0.262
RWC	P	-0.006	0.003	0.014	-0.013	0.011	0.000	-0.004	0.004	0.009	0.003	0.005	**0.038**	-0.031	0.029	0.008	0.120
	G	0.132	-0.003	-0.091	0.152	-0.062	0.024	0.078	-0.037	-0.058	-0.012	-0.058	**-0.298**	0.293	-0.233	-0.057	0.096
MTS	P	0.006	0.001	-0.001	0.006	-0.003	0.002	0.002	0.000	0.000	-0.001	-0.001	-0.010	**0.012**	-0.008	-0.004	-0.127
	G	-0.082	0.000	0.018	-0.070	0.063	-0.014	-0.020	-0.003	0.013	0.017	0.022	0.151	**-0.153**	0.126	0.056	-0.162
ATR	P	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	**-0.002**	0.000	0.272**
	G	-0.033	0.008	0.011	-0.041	-0.005	-0.005	-0.009	0.001	-0.011	0.018	0.009	0.050	-0.053	**0.065**	0.014	0.317
ACR	P	-0.004	-0.003	-0.014	-0.003	0.009	-0.004	0.003	-0.008	-0.005	-0.004	0.003	0.004	-0.007	0.005	**0.022**	-0.104
	G	-0.076	-0.051	-0.215	-0.043	0.147	-0.066	0.036	-0.126	-0.084	-0.064	0.066	0.058	-0.110	0.065	**0.304**	-0.110

Residual factors = 0.061 and Bold figures indicate direct effects

DFF: days to 50 per cent flowering; SFL: size of flag leaf excluding sheath; PH: plant height; EBT: ear bearing tillers plant^{-1}; PL: panicle length; G/P: grains panicle^{-1}; S/P: spikelets panicle^{-1}; SF: spikelet fertility; TW: test-weight; GY/P: grain yield plant^{-1}; BY/P: biological yield plant^{-1}; HI: harvest-index; RWC: relative water content; MTS: membrane thermo stability; ATR: apparent translocation rate and ACR: apparent contribution rate

associations in rice. The characters identified as important direct and indirect yield contributing traits, merit due consideration while devising selection strategy for developing high yield ideotypes having proper balance of yield components and physiological traits favoring their performance in irrigated and drought conditions. The results indicated that selection favoring higher apparent contribution rate, biological yield plant^{-1}, harvest index and grain yield plant^{-1} with a reasonable balance for grains panicle^{-1} would help to achieve higher grain yield in this population.

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