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Influence of environment on characters association in rice hybrids and varieties

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ABSTRACT

Character association and path analysis with 29 genotypes in rice hybrids and varieties over 3 environments revealed that grain yield significantly and positively correlated with plant height, 1000-grain weight, kernel length and breadth in most of the locations and on pooled basis. Number of grains per panicle exhibited a significant positive correlation with grain yield in one location, which indicated that relation between filled grains per panicle and yield was highly variable in comparison to other traits. Based on correlation coefficient and path analysis, productive tillers per plant, filled grains per panicle and 1000-seed weight were considered as prime yield components in hybrid rice and there should be a balance between yield and height, as the later is highly influencing indirectly yield potential in hybrids through panicle length and grain per panicle. The head rice recovery and kernel length were negatively correlated. The correlation between other quality parameters was highly variable with changing environment.

Key words: *Rice, correlation, path analysis, grain yield, quality*

In rice, grain yield is a complex character and is dependent on its contributing traits. A study was envisaged on character association, to assess the relationships among yield and its components and to have an insight into the causes for higher yield in hybrids and varieties. Further, location wise analysis helps to understand the variation in association under different environments and to identify a stable character influencing the yield for further concentration and emphasis in breeding programmes. Path coefficient analysis allows separation of the direct effect and their indirect effects through other attributes by partitioning the correlations (Wright 1921).Hence, the path coefficient analysis was done to know the direct and indirect effects of yield components on yield for 3 locations separately and pooled.

Twenty nine rice genotypes (18 hybrids and 11 varieties), which includes both pre-release and released hybrids were grown during wet season 2012 in a randomized block design with 3 replications in 3 locations (Kampasagar, Jagtial and Rajendranagar). A single row plot was maintained for each entry adopting a spacing of 15 x 15cm with recommended agronomic practice was followed. Data were recorded on five randomly selected competitive plants from each genotype from each replication for days to 50 % flowering, plant height, panicle length, effective tillers plant^{-1}, filled grains panicle^{-1}, 1000 seed weight, seed yield plant^{-1}, kernel length, kernel breadth, kernel L/B ratio, kernel length after cooking, kernel elongation ratio (KER), volume expansion ratio (VER) and head rice recovery (HRR) in three locations. Simple correlation coefficients (r) for grain yield and its components and quality characters were calculated involving both hybrids and varieties by adopting the method given by Panse and Sukhathme (1985) and path coefficients analysis was carried out according to Dewey and Lu (1959).

Varying levels of correlation coefficients between yield components and quality characters suggested presence of considerable amount of interaction between genotypes and environments with respect to characters studied (Table 1 and 2).

Pooled analysis revealed that the associations between yield and all the yield components except days to 50% flowering, sterility percentage, L/B ratio were highly significant and positive. Grain yield plant^{-1} has exhibited a positive correlation with days to 50% flowering, productive tillers (Surek and Beser 2003) and filled grains panicle^{-1}, grain length(Nayak *et al*. 2004 and Nandan *et al*. 2010) as reported earlier. Raju *et al*. (2003) also reported a positive association between grain yield and filled grains panicle^{-1} in rice hybrids. With respect to location wise correlations, plant height, kernel length, in three; panicle length, effective tillers plant^{-1}, 1000 grain weight and kernel breadth in two and number of grains panicle^{-1} in one location registered significant correlations with grain yield, which indicated that relation between filled grains panicle^{-1} and yield was highly variable in comparison to other relations (Table 1). In contrary to the present study, Nayak *et al.* (2004) reported that among the various components, filled grains panicle^{-1} was the less variable trait and it maintained a significant positive correlation with grain yield in all the environments. Further, they reported higher influence on days to 50% flowering, as in the case of present findings. The association between days to 50% flowering and grain yield was negative and significant at two locations and on pooled basis. Plant height and panicle length had significant positive correlation with 1000 grain weight, kernel length and kernel breadth. A highly significant positive correlation between plant height and panicle length and also panicle length in turn with filled grains on pooled analysis indicated long panicles had increased sink size.

No. of productive tillers did not have significant correlations with other components when location wise analysis was made, however on pooled basis it had a significant negative association with sterility percentage, which may probably due to presence of more unproductive tillers and wastage of photosynthates in supporting increased sink size. A strong negative association existed between filled grains panicle^{-1} and 1000grain weight, kernel length and breadth, however, the association between total number of grains and filled grains was highly significant and positive. It appears that kernel characters *viz.*, length, breadth and L/B ratio together with 1000 grain weight need to be given due to attention for improvement of hybrid rice yields along with other traits as they were interrelated positively besides individually exhibiting significant positive correlations with grain yield (Table 1).

Among the quality characters, head rice recovery (HRR) occupies very important position, as higher percentage of head rice is nearly to realize higher whole grain per unit area. This trait had significant negative correlation with kernel length, breadth in most of the locations and pooled. However, its association was positive and significant with milling percentage (Table 2).

The relation between kernel length and kernel elongation ratio (KER) was negative but its association with KLAC was positive and significant. The cooking quality traits, *viz.* KER, VER and WU exhibited mostly a significant negative association with kernel length and breadth. Direct effects through path analysis revealed that kernel length and L/B ratio as direct positive effect on water uptake (Table 4). Path analysis revealed that plant height, effective tillers plant^{-1}, filled grains panicle^{-1}, 1000 grain weight (except at kampasagar) and kernel breadth (except at Jagtial) exhibited direct positive effect on grain yield plant^{-1}. Panicle length though had a significant positive correlation with grain yield, its direct influence was negative. At one location, Jagtial, the kernel length had shown a direct positive effect on grain yield, though on pooled basis, the magnitude was very less.The character, L/B ratio exhibited positive direct effect at two locations (Kampasagar and Rajendranagar)and pooled basis with grain yield. Indirect and direct contribution to grain yield through 1000 grain weight and kernel breadth was observed in at least two locations which suggested that their two traits in turn were highly related (Table 3).

Based on the above analysis total number of grains plant^{-1}, filled grains panicle^{-1} and 1000 seed weight can be considered as prime yield components in hybrid rice and they showed a balance between yield and height, as the later is highly influencing yield potential in hybrids through panicle length and grains panicle^{-1}.

Table 1. Simple correlation coefficients for yield and its component characters for three different locations and pooled

Characters	Location	Days to 50% flowering	Plant height	Panicle length	Effective tillers plant^{-1}	Total no. grains panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage	1000 seed weight	Kernel length	Kernel breadth	L/B ratio	Seed yield plant^{-1}
Days to 50% flowering	**I**	**1.0000**	-0.3150**	-0.4810**	-0.1085	0.1733	0.2184*	0.0304	-0.4775**	-0.5968**	-0.4188**	-0.2293*	-0.2655**
	II	**1.0000**	0.0161	-0.3352**	0.0802	0.2480*	0.3343**	0.2776**	-0.5000**	-0.4969**	-0.3662**	-0.1412	-0.2969**
	III	**1.0000**	0.1094	-0.2619**	-0.1796	0.1849	0.1764	0.0567	-0.2215*	-0.2726**	-0.2032	-0.0990	0.0342
	P	**1.0000**	-0.3730**	-0.5934**	-0.2097**	-0.1974**	-0.0755	-0.1134	-0.3234**	-0.2548**	-0.2809**	0.0138	-0.4005**
Plant height	**I**		**1.0000**	0.6570**	0.1667	0.1069	0.1551	-0.1115	0.4989**	0.5147**	0.5453**	-0.0077	0.5934**
	II		**1.0000**	0.7190**	-0.2192**	0.0267	-0.0689	0.4170**	0.5083**	0.4834**	0.4801**	-0.0003	0.4244**
	III		**1.0000**	0.5255**	0.0772	0.1265	0.0933	0.1695	0.5363**	0.4822**	0.5468**	0.0280	0.2533*
	P		**1.0000**	0.8233**	-0.1236*	0.2872**	0.2840**	0.0286	0.3627**	0.3130**	0.3122**	0.0269	0.4658**
Panicle length	**I**			**1.0000**	0.0380	-0.0596	-0.0526	-0.0307	0.4950**	0.6296**	0.3848**	0.2725**	0.4711**
	II			**1.0000**	-0.0668	0.1788	0.0133	0.2281*	0.5314**	0.6156**	0.3874**	0.2529**	0.5487**
	III			**1.0000**	0.2112*	0.1326	0.0391	0.1906	0.4425**	0.3991**	0.4678**	0.0226	0.0767
	P			**1.0000**	-0.0076	0.3328**	0.2652**	0.0730	0.3547**	0.3374**	0.2664**	0.1017	0.4704**
Effective tillers plant^{-1}	**I**				**1.0000**	0.0416	0.1564	-0.4077**	-0.0859	-0.0193	0.1144	-0.1317	0.4777**
	II				**1.0000**	0.0547	-0.0284	-0.0064	-0.1967	-0.1422	-0.0994	-0.0563	0.1932
	III				**1.0000**	0.1267	-0.0429	0.1739	0.0334	0.0849	-0.0464	0.1507	0.3688**
	P				**1.0000**	0.1173	0.0064	0.2039**	-0.0382	-0.0220	0.0499	-0.0817	0.3327**
Total no. grains panicle^{-1}	**I**					**1.0000**	0.9148**	0.1259	-0.5372**	-0.4806**	-0.4109**	-0.1187	0.1483
	II					**1.0000**	0.7971**	0.2219*	-0.3508**	-0.1454	-0.2767**	0.1427	0.3043**
	III					**1.0000**	0.6869**	0.5530**	-0.4161*	-0.4751**	-0.2912**	-0.2559*	0.1630
	P					**1.0000**	0.8182**	0.3385**	-0.3440**	-0.3211**	-0.2530**	-0.0994	0.3491**
Filled grains panicle^{-1}	**I**						**1.0000**	-0.0877	-0.4583**	-0.4704**	-0.2891**	-0.2292*	0.2726**
	II						**1.0000**	-0.1175	-0.4952**	-0.3319**	-0.3492**	0.0139	0.1755
	III						**1.0000**	-0.0940	-0.3943**	-0.3140**	-0.2727**	-0.1031	0.1186
	P						**1.0000**	-0.0719	-0.4005**	-0.3495**	-0.2773**	-0.1094	0.2903**

I – Kampasagar, II – Jagtial *Significant at 5% level **Significant at 1% level
III – Rajendranagar, P – Pooled

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Characters	Location	Days to 50% flowering	Plant height	Panicle length	Effective tillers plant^{-1}	Total no. grains panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage	1000 seed weight	Kernel length	Kernel breadth	L/B ratio	Seed yield plant^{-1}
Sterility percentage	**I**							**1.0000**	-0.201*	-0.0391	-0.3191**	0.2811**	-0.3654**
	II							**1.0000**	0.0985	0.0887	0.0985	-0.0366	0.0315
	III							**1.0000**	-0.0942	-0.2881**	-0.0895	-0.2288*	0.1277
	P							**1.0000**	-0.0080	-0.1269*	0.0083	-0.1476*	0.0769
1000 seed weight	**I**								**1.0000**	0.8046**	0.7700**	0.0812	0.2284*
	II								**1.0000**	0.8378**	0.7618**	0.0846	0.4664**
	III								**1.0000**	0.8567**	0.7904**	0.2448*	0.1999
	P								**1.0000**	0.8220**	0.7729**	0.1151*	0.3229**
Kernel length	**I**									**1.0000**	0.5392**	0.5195**	0.2989**
	II									**1.0000**	0.6117**	0.4448**	0.5300**
	III									**1.0000**	0.6357**	0.5746**	0.2012*
	P									**1.0000**	0.5827**	0.5130**	0.3098**
Kernel breadth	**I**										**1.0000**	-0.432**	0.4270**
	II										**1.0000**	-0.432**	0.4787**
	III										**1.0000**	-0.2089*	0.1003
	P										**1.0000**	-0.374**	0.3557**
L/B ratio	**I**											**1.0000**	-0.1185
	II											**1.0000**	0.0482
	III											**1.0000**	0.1756
	P											**1.0000**	-0.0187
Seed yield plant^{-1}	**I**												**1.0000**
	II												**1.0000**
	III												**1.0000**
	P												**1.0000**

I – Kampasagar, II – Jagtial *Significant at 5% level **Significant at 1% level
III – Rajendranagar, P – Pooled

Table 2. Simple correlation coefficients for quality characters for three different locations and pooled

Character	Location	Kernel length	Kernel breadth	L/B ratio	Hulling percentage	Milling percentage	HRR	KLAC	Elongation ratio	VER	Water uptake
Kernel length	**I**	**1.0000**	0.5392**	0.5195**	-0.1046	0.1478	-0.3650**	0.7355**	-0.5419**	-0.2876**	-0.0080
	II	**1.0000**	0.6117**	0.4448**	-0.0044	-0.0194	-0.3267**	0.6758**	-0.4865**	-0.5245**	-0.6358**
	III	**1.0000**	0.6357**	0.5746**	-0.0693	0.1361	-0.1125	0.6562**	-0.3934**	-0.2867**	0.0228
	P	**1.0000**	0.5827**	0.5130**	-0.0655	0.0965	-0.2375**	0.6483**	-0.4474**	-0.3640**	-0.1922**
Kernel breadth	**I**		**1.0000**	-0.4320**	-0.2181**	0.0597	-0.1889	0.4020**	-0.3029**	-0.2387*	-0.2977**
	II		**1.0000**	-0.4321**	-0.3765**	-0.2545*	-0.5985**	0.4997**	-0.2147*	-0.4453**	-0.5168**
	III		**1.0000**	-0.2089*	-0.1214	0.1785	-0.0136	0.5280**	-0.1414	-0.1906	-0.2867**
	P		**1.0000**	-0.3748**	-0.1709**	0.0128	-0.3451**	0.4962**	-0.1475**	-0.2529**	-0.3853**
L/B ratio	**I**			**1.0000**	0.1010	0.1009	-0.1917	0.3861**	-0.2610*	-0.0694	0.2757**
	II			**1.0000**	0.4143**	0.2777**	0.3080**	0.1833	-0.3301**	-0.1003	-0.1252
	III			**1.0000**	0.0367	-0.0233	-0.1394	0.2693**	-0.3357**	-0.1616	0.3182**
	P			**1.0000**	0.0971	0.0875	0.0796	0.2067**	-0.3516**	-0.1551**	0.1863**
Hulling percentage	**I**				**1.0000**	0.5434**	-0.1990	-0.1070	-0.0093	-0.1217	0.1872
	II				**1.0000**	0.4501**	0.2189*	0.0267	0.0307	0.0110	0.2656*
	III				**1.0000**	0.5099**	0.3266**	-0.4333**	-0.4446**	0.1477	-0.2087*
	P				**1.0000**	0.4047**	0.0789	-0.2088*	-0.1745**	0.0908	-0.0126
Milling Percentage	**I**					**1.0000**	0.0719	0.2961**	0.1485	-0.3589**	0.1268
	II					**1.0000**	0.4441**	-0.1620	-0.1453	-0.3043**	0.2428*
	III					**1.0000**	0.6527**	-0.0971	-0.2665**	-0.2367*	-0.0796
	P					**1.0000**	0.4465**	-0.0515	-0.1601	-0.2785**	0.0554

I – Kampasagar, II – Jagtial *Significant at 5% level **Significant at 1% level
III – Rajendranagar, P – Pooled

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Character	Location	Kernel length	Kernel breadth	L/B ratio	Hulling percentage	Milling percentage	HRR	KLAC	Elongation ratio	VER	Water uptake
HRR	**I**						**1.0000**	-0.1995	0.2753**	0.4013**	-0.2417*
	II						**1.0000**	-0.3095**	0.0999	0.1684	0.2457*
	III						**1.0000**	-0.1869	-0.0842	0.1044	-0.1122
	P						**1.0000**	-0.2705**	-0.0030	0.1144	0.0487
KLAC	**I**							**1.0000**	0.1549	-0.3262**	-0.0167
	II							**1.0000**	0.3071	-0.2991	-0.3757
	III							**1.0000**	0.4272**	-0.2138*	0.2169*
	P							**1.0000**	0.3806**	-0.1848**	-0.0702
Elongation ratio	**I**								**1.0000**	-0.0092	0.0104
	II								**1.0000**	0.3084**	0.3661**
	III								**1.0000**	0.0499	0.2640*
	P								**1.0000**	0.1994**	0.1718**
VER	**I**									**1.0000**	-0.2421*
	II									**1.0000**	0.2718**
	III									**1.0000**	-0.0379
	P									1.0000	-0.0022
Water uptake	**I**										**1.0000**
	II										**1.0000**
	III										**1.0000**
	P										**1.0000**

I – Kampasagar, II – Jagtial *Significant at 5% level **Significant at 1% level
III – Rajendranagar, P – Pooled

Table 3. Direct and Indirect effects for yield and its component characters for three different locations and pooled

Characters	Location	Days to 50% flowering	Plant height	Panicle length	Effective tillers plant^{-1}	Total no. grains panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage	1000 seed weight	Kernel length	Kernel breadth	L/B ratio	Seed yield plant^{-1}
Days to	**I**	**0.0416**	-0.0525	-0.1001	-0.0288	-0.0080	0.0734	-0.0042	0.1937	-0.1174	-0.2292	-0.0340	-0.2655
50% flowering	**II**	**-0.1422**	0.0047	0.0215	0.0273	0.1008	0.0588	-0.0531	-0.1361	-0.6049	0.2968	0.1297	-0.2969
	III	**0.0623**	0.0076	0.0680	-0.0685	0.0018	0.0529	0.0107	-0.0641	0.0248	-0.0389	-0.0224	0.0342
	P	**-0.0831**	-0.0934	0.0344	-0.0682	-0.0578	-0.0104	0.0079	-0.0387	-0.0064	-0.0866	0.0018	-0.4005
Plant height	**I**	-0.0131	**0.1667**	0.1367	0.0442	-0.0049	0.0521	0.0155	-0.2024	0.1012	0.2984	-0.0011	0.5934
	II	-0.0023	**0.2903**	-0.0461	-0.0745	0.0108	-0.0121	-0.0798	0.1384	0.5885	-0.3891	0.0002	0.4244
	III	0.0068	**0.0699**	-0.1365	0.0294	0.0012	0.0280	0.0319	0.1551	-0.0438	0.1048	0.0063	0.2533
	P	0.0310	**0.2503**	-0.0477	-0.0402	0.0841	0.0392	-0.0020	0.0434	0.0079	0.0962	0.0035	0.4658
Panicle	**I**	-0.0200	0.1095	**0.2081**	0.0101	0.0028	-0.0177	0.0043	-0.2008	0.1238	0.2105	0.0404	0.4711
length	**II**	0.0477	0.2088	**-0.0641**	-0.0227	0.0727	0.0023	-0.0436	0.1447	0.7494	-0.3140	-0.2324	0.5487
	III	-0.0163	0.0367	**-0.2597**	0.0805	0.0013	0.0117	0.0359	0.1280	-0.0363	0.0897	0.0051	0.0767
	P	0.0493	0.2061	**-0.0579**	-0.0025	0.0975	0.0366	-0.0051	0.0425	0.0085	0.0821	0.0133	0.4704
Effective	**I**	-0.0045	0.0278	0.0079	**0.2650**	-0.0019	0.0526	0.0568	0.0348	-0.0038	0.0626	-0.0195	0.4777
tillers plant^{-1}	**II**	-0.0114	-0.0636	0.0043	**0.3400**	0.0222	-0.0050	0.0012	-0.0536	-0.1732	0.0806	0.0517	0.1932
	III	-0.0112	0.0054	-0.0549	**0.3813**	0.0012	-0.0129	0.0328	0.0097	-0.0077	-0.0089	0.0341	0.3688
	P	0.0174	-0.0309	0.0004	**0.3252**	0.0344	0.0009	-0.0143	-0.0046	-0.0006	0.0154	-0.0107	0.3327
Total no.	**I**	0.0072	0.0178	-0.0124	0.0110	**-0.0463**	0.3075	-0.0175	0.2179	-0.0945	-0.2248	-0.0176	0.1483
grains panicle^{-1}	**II**	-0.0353	0.0077	-0.0115	0.0186	**0.4064**	0.1401	-0.0425	-0.0955	-0.1770	0.2243	-0.1311	0.3043
	III	0.0115	0.0088	-0.0344	0.0483	**0.0096**	0.2059	0.1041	-0.1204	0.0432	-0.0558	-0.0579	0.1630
	P	0.0164	0.0719	-0.0193	0.0382	**0.2929**	0.1130	-0.0237	-0.0412	-0.0081	-0.0780	-0.0130	0.3491
Filled grains	**I**	0.0091	0.0259	-0.0110	0.0414	-0.0424	**0.3361**	0.0122	0.1859	-0.0925	-0.1582	-0.0340	0.2726
panicle^{-1}	**II**	-0.0475	-0.0200	-0.0009	-0.0096	0.3239	**0.1758**	0.0225	-0.1348	-0.4041	0.2831	-0.0127	0.1755
	III	0.0110	0.0065	-0.0101	-0.0164	0.0066	**0.2998**	-0.0177	-0.1141	0.0285	-0.0523	-0.0233	0.1186
	P	0.0063	0.0711	-0.0154	0.0021	0.2397	**0.1381**	0.0050	-0.0479	-0.0088	-0.0855	-0.0143	0.2903

* Significant at 5% level, Bold values – Direct effect, I – Kampasagar, II – Jagtial Residual effect: I =0.6080 **Significant at 1% level, Normal values – Indirect effect, III – Rajendranagar, P – Pooled II =0.5618

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Characters	Location	Days to 50% flowering	Plant height	Panicle length	Effective tillers plant^{-1}	Total no. grains panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage	1000 seed weight	Kernel length	Kernel breadth	L/B ratio	Seed yield plant^{-1}
Sterility percentage	**I**	0.0013	-0.0186	-0.0064	-0.1080	-0.0058	-0.0295	**-0.1392**	0.0815	-0.0077	-0.1746	0.0417	-0.3654
	II	-0.0395	0.1211	-0.0146	-0.0022	0.0902	-0.0206	**-0.1914**	0.0268	0.1080	-0.0799	0.0336	0.0315
	III	0.0035	0.0119	-0.0495	0.0663	0.0053	-0.0282	**0.1883**	-0.0273	0.0262	-0.0172	-0.0517	0.1277
	P	0.0094	0.0072	-0.0042	0.0663	0.0992	-0.0099	**-0.0701**	-0.0010	-0.0032	0.0026	-0.0193	0.0769
1000 seed weight	**I**	-0.0198	0.0832	0.1030	-0.0228	0.0249	-0.1541	0.0280	**-0.4057**	0.1582	0.4214	0.0120	0.2284
	II	0.0711	0.1476	-0.0341	-0.0669	-0.1426	-0.0870	-0.0189	**0.2723**	1.0200	-0.6174	-0.0778	0.4664
	III	-0.0138	0.0375	-0.1149	0.0127	-0.0040	-0.1182	-0.0177	**0.2893**	-0.0779	0.1515	0.0554	0.1999
	P	0.0269	0.0908	-0.0205	-0.0124	-0.1007	-0.0553	0.0006	**0.1197**	0.0207	0.2383	0.0151	0.3229
Kernel length	**I**	-0.0248	0.0858	0.1310	-0.0051	0.0223	-0.1581	0.0054	-0.3264	**0.1967**	0.2951	0.0771	0.2989
	II	0.0707	0.1403	-0.0394	-0.0484	-0.0591	-0.0583	-0.0170	0.2281	**1.2174**	-0.4957	-0.4087	0.5300
	III	-0.0170	0.0337	-0.1036	0.0324	-0.0046	-0.0941	-0.0543	0.2478	**-0.0909**	0.1218	0.1299	0.2012
	P	0.0212	0.0783	-0.0195	-0.0071	-0.0941	-0.0483	0.0089	0.0984	**0.0252**	0.1797	0.0672	0.3098
Kernel breadth	**I**	-0.0174	0.0909	0.0801	0.0303	0.0190	-0.0972	0.0444	-0.3124	0.1060	**0.5472**	-0.0641	0.4270
	II	0.0521	0.1394	-0.0248	-0.0338	-0.1125	-0.0614	-0.0189	0.2074	0.7446	**-0.8105**	0.3969	0.4787
	III	-0.0127	0.0382	-0.1215	-0.0177	-0.0028	-0.0818	-0.0169	0.2287	-0.0578	**0.1917**	-0.0472	0.1003
	P	0.0233	0.0781	-0.0154	0.0162	-0.0741	-0.0383	-0.0006	0.0925	0.0147	**0.3083**	-0.0491	0.3557
L/B ratio	**I**	-0.0095	-0.0013	0.0567	-0.0349	0.0055	-0.0770	-0.0391	-0.0329	0.1022	-0.2364	**0.1484**	-0.1185
	II	0.0201	-0.0001	-0.0162	-0.0191	0.0580	0.0024	0.0070	0.0230	0.5415	0.3502	**-0.9187**	0.0482
	III	-0.0062	0.0020	-0.0059	0.0574	-0.0025	-0.0309	-0.0431	0.0708	-0.0522	-0.0400	**0.2261**	0.1756
	P	-0.0011	0.0067	-0.0059	-0.0266	-0.0291	-0.0151	0.0103	0.0138	0.0129	-0.1156	**0.1310**	-0.0187

* Significant at 5% level, Bold values – Direct effect, I – Kampasager, II – Jagitial Residual effect: III = 0.8365
**Significant at 1% level, Normal values – Indirect effect, III – Rajendranager, P – Pooled P =0.6918

Table 4. Direct and Indirect effects for quality characters for three different locations and pooled

Character	Location	Kernel length	Kernel breadth	L/B ratio	Hulling percentage	Milling percentage	HRR	KLAC	Elongation ratio	VER	Water uptake
Kernel length	**I**	**1.1762**	-0.7606	-0.5006	0.0056	0.0196	0.0833	-0.0776	-0.0141	0.0601	-0.0080
	II	**-3.8667**	1.2116	0.8593	-0.0006	-0.0035	0.0377	0.7401	0.3594	0.0270	-0.6358
	III	**0.8367**	-0.2780	0.0963	0.0140	0.0381	0.0185	-0.3632	-0.3106	-0.0290	0.0228
	P	**0.3134**	-0.2210	0.0607	0.0083	0.0192	0.0442	-0.2285	-0.2002	0.0116	-0.1922
Kernel breadth	**I**	0.6342	**-1.4106**	0.4163	0.0118	0.0079	0.0431	-0.0424	-0.0079	0.0499	-0.2977
	II	-2.3651	**1.9809**	-0.8346	-0.0494	-0.0464	0.0691	0.5473	0.1586	0.0229	-0.5168
	III	0.5319	**-0.4373**	-0.0350	0.0246	0.0500	0.0022	-0.2923	-0.1116	-0.0193	-0.2867
	P	0.1826	**-0.3792**	-0.0444	0.0216	0.0025	0.0643	-0.1749	-0.0660	0.0081	-0.3853
L/B ratio	**I**	0.6111	0.6094	**-0.9635**	-0.0054	0.0134	0.0437	-0.0407	-0.0068	0.0145	0.2757
	II	-1.7201	-0.8559	**1.9317**	0.0543	0.0506	-0.0356	0.2007	0.2438	0.0052	-0.1252
	III	0.4808	0.0914	**0.1676**	-0.0074	-0.0065	0.0230	-0.1491	-0.2651	-0.0164	0.3182
	P	0.1608	0.1421	**0.1183**	-0.0123	0.0174	-0.0148	-0.0728	-0.1573	0.0049	0.1863
Hulling percent	**I**	-0.1230	0.3076	-0.0974	**-0.0539**	0.0720	0.0454	0.0113	-0.0002	0.0254	0.1872
	II	0.0172	-0.7458	0.8004	**0.1311**	0.0821	-0.0253	0.0292	-0.0227	-0.0006	0.2656
	III	-0.0580	0.0531	0.0061	**-0.2026**	0.1428	-0.0538	0.2399	-0.3511	0.0150	-0.2087
	P	-0.0205	0.0648	0.0115	**-0.1267**	0.0804	-0.0147	0.0736	-0.0781	-0.0029	-0.0126
Milling percent	**I**	0.1738	-0.0843	-0.0972	-0.0293	**0.1325**	-0.0164	-0.0312	0.0039	0.0750	0.1268
	II	0.0748	-0.5042	0.5365	0.0590	**0.1823**	-0.0513	-0.1774	0.1074	0.0157	0.2428
	III	0.1139	-0.0781	-0.0039	-0.1033	**0.2800**	-0.1075	0.0537	-0.2104	-0.0240	-0.0796
	P	0.0302	-0.0049	0.0104	-0.0513	**0.1987**	-0.0831	0.0181	-0.0716	0.0089	0.0554

* Significant at 5% level, Bold values – Direct effect, I – Kampasagar, II – Jagtial, Residual effect : I =0.8606
**Significant at 1% level, Normal values – Indirect effect, III – Rajendranagar, P – Pooled II =0.6726

Contd.....

Character	Location	Kernel length	Kernel breadth	L/B ratio	Hulling percentage	Milling percentage	HRR	KLAC	Elongation ratio	VER	Water uptake
HRR	**I**	-0.4293	0.2665	0.1847	0.0107	0.0095	**-0.2281**	0.0210	0.0072	-0.0839	-0.2417
	II	1.2634	-1.1856	0.5950	0.0287	0.0810	**-0.1154**	-0.3389	-0.0738	-0.0087	0.2457
	III	-0.0941	0.0060	-0.0234	-0.0662	0.1827	**-0.1647**	0.1034	-0.0665	0.0106	-0.1122
	P	-0.0744	0.1309	0.0094	-0.0100	0.0887	**-0.1862**	0.0953	-0.0013	-0.0036	0.0487
KLAC	**I**	0.8651	-0.5670	-0.3721	0.0058	0.0392	0.0455	**-0.1054**	0.0040	0.0682	-0.0167
	II	-2.6130	0.9899	0.3540	0.0035	-0.0295	0.0357	**1.0952**	-0.2268	0.0154	-0.3757
	III	0.5491	-0.2309	0.0451	0.0878	-0.0272	0.0308	**-0.5535**	0.3373	-0.0217	0.2169
	P	0.2032	-0.1882	0.0245	0.0264	-0.0102	0.0504	**-0.3524**	0.1703	0.0059	-0.0702
Elongation ratio	**I**	-0.6374	0.4272	0.2515	0.0005	0.0197	-0.0628	-0.0163	**0.0260**	0.0019	0.0104
	II	1.8812	-0.4252	-0.6376	0.0040	-0.0265	-0.0115	0.3363	**-0.7387**	-0.0159	0.3661
	III	-0.3291	0.0618	-0.0562	0.0901	-0.0746	0.0139	-0.2365	**0.7897**	0.0051	0.2640
	P	-0.1402	0.0559	-0.0416	0.0221	-0.0318	0.0006	-0.1341	**0.4474**	-0.0064	0.1718
VER	**I**	-0.3383	0.3367	0.0668	0.0066	-0.0476	-0.0915	0.0344	-0.0002	**-0.2090**	-0.2421
	II	2.0280	-0.8820	-0.1938	0.0014	-0.0555	-0.0194	-0.3276	-0.2279	**-0.0515**	0.2718
	III	-0.2399	0.0833	-0.0271	-0.0299	-0.0663	-0.0172	0.1183	0.0394	**0.1013**	-0.0379
	P	-0.1141	0.0959	-0.0184	-0.0115	-0.0553	-0.0213	0.0651	0.0892	**-0.0318**	-0.0022

* Significant at 5% level, Bold values – Direct effect, I – Kampasagar, II – Jagtial Residual effect : III = 08241
**Significant at 1% level, Normal values – Indirect effect, III – Rajendranagar, P – Pooled P =0.8871

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