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Correlation matrix and path analysis for yield attributes in rice under various establishment methods

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Abstract
Yield attributing characters were studied for correlation and regression analysis. The aims were to determine the relationship existing between grain yield and other yield attributing characters so as to identify the plant characters that could serve as good yield components to improve rice yield under different rice crop establishment methods. Total tiller density had positive and significant association with number of effective tillers under all the methods of establishment of rice crop. But, dry matter accumulation had negative association with grain yield under direct seeded rice due to accumulation in the stem before grain filling and poor translocation of photosynthates from the source to the sink. Total tiller density, 1000 grain weight and filled grains per panicle contributed the maximum to grain yield under direct seeded rice, non-puddled transplanted rice and puddled transplanted rice, respectively.

Keywords: DSR, NPTR, PTR, correlation coefficient, regression coefficient, path analysis

Introduction
Rice (*Oryza sativa* L.) feeds about 90% of the world population especially in Asia and provides 19% of global calories consumed by human (IRRI, 2014). Predictions indicate that world's rice production should increase to 880 million tonnes in the year 2025 to meet the rice demand of the ever-increasing human population. Low yield in Eastern India including Odisha is due to dominance of monsoon dependent rice production system which is subjected to vagaries of nature. In fact rice is the only suitable crop for medium and low land situation during monsoon season due to presence of aerenchymatous tissue and its tolerance to standing water. Thus, the agriculture in Odisha is dominated by rice based production system. Transplanting is the most popular method of rice establishment in those areas. The yield of transplanted rice is generally believed to be higher than that of dry-seeded rice. This method, however, has high water and labor requirements. In recent years, the direct seeding method has been promoted as a replacement for transplanting to address this problem of labor scarcity and high water demand. The labor requirement of direct seeding is only about 34% that of transplanted rice (Ho Nai-Kin *et al.*, 2002) [4]. Another alternate method of rice establishment is growing i.e. non Puddled Transplanted Rice. The performance of rice transplanting under non puddled (after cultivation in dry soil) condition has been reported to give better yield than puddled transplanting in Karnal, Haryana (Yadav *et al*., 2010) [10]. The present research study was conducted to find out the quantitative relationship among different yield attributing characters under different rice establishment methods, direct and indirect contribution of these parameters towards grain yield and to identify the better crop establishment method for higher crop productivity.

Materials and Methods
The experiment was conducted at Agronomy Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha with a latitude of 20^0 15'N, longitude of 85^0 52'E and altitude of 25.9 m above mean sea level during *Kharif* season of 2014 and 2015. The total rainfall received during cropping period for the year 2014 and 2015 was 1328.8 mm and 851.1 mm, respectively. The experiment was laid out in split plot design with three crop establishment methods *viz.* direct seeded rice (DSR), non-puddled transplanted rice (NPTR) and puddled transplanted rice (PTR) allocated to main plots and three cultivar duration groups

viz. short duration('Arize 6129'), medium duration('Arize 6444') and long duration ('Swarna') allotted to sub plotsin *kharif* season and treatments replicated thrice. The experimental field was initially dry ploughed with tractor drawn disc harrow followed by cultivator and rotavator to get fine tilth. Laser leveling was also done to get perfect levelling. For preparing the field under Puddled Transplanted Rice (PTR), the ploughed field was given flooded irrigation after fine tilth. Then the field was puddled well with cage wheel and leveled with wooden leveling board. Under Non- Puddled Transplanted Rice (NPTR) plot after fine tilth 50 mm of water was allowed to soak the soil for smoother transplanting of seedling. But in dry seeded rice (DSR) sowing was done with the help of zero seed drill after getting fine tilth.

Correlation analysis among yield and yield components is one of the prerequisite techniques to determine the influence of environment on productivity and yield potential. Determination of correlation coefficient between various characters helps to obtain best combination of attributes for obtaining higher return per unit area. But regression analysis is done to quantify the relationship between the dependent variable and the independent variables. Path analysis is an extension of multiple regression. It goes beyond regression in that it allows for the analysis of more complicated models. In particular, it can examine situations in which there are several final dependent variables and those in which there are "chains" of influence, in that variable A influences variable B, which in turn affects variable C.

Statistical analysis was done for correlation coefficient following procedure given, adopted and described by Singh and Chaudhary (1995) [8]. The procedure given, adopted and described by Dewey and Lu (1959) [3] was adopted for path analysis. Data were analyzed with 9 sets parameter having 15 numbers of observations under each parameter with 13 degree of freedom.

Results and Discussion

Correlation and Path analysis study of Direct Seeded Rice (DSR)

Under direct seeded rice, total tiller registered positive and significant association with number of effective tillers; LAI at 50% flowering and number of effective tillers with filled grains per panicle; filled grains per panicle with 1000 grain weight (Table 1 and Figure 1). Plant height, total tiller density, LAI at 50% flowering, number of effective tillers per square meter and straw yield exhibited positive correlation with grain yield. However, the correlation was statistically non-significant. There was non-significant negative correlation between dry matter accumulations with grain yield.

Among all the characters studied under path coefficient analysis, the number of total tillers per unit area had the maximum positive direct effect and dry matter accumulation had maximum negative direct effect on grain yield (Table 2 and Figure 2). On the other hand positive direct effect on grain yield were recorded in case of plant height, total tiller, LAI at 50% flowering, number of effective tillers and straw yield, while negative direct effect on grain yield were recorded in case of dry matter accumulation at PM, filled grains per panicle and 1000 grain weight. The indirect expression of tiller density on grain yield through all the aforesaid characters were negative except LAI at 50% flowering and number of effective tillers^{-2}. The indirect effect expression of dry matter accumulation on grain yield through all the aforesaid characters were negative except plant height, LAI at 50% flowering, filled grains per panicle and 1000 grain weight.

Correlation and Path analysis studies of non-puddled transplanted rice (NPTR)

Under non-puddled transplanting, total tiller registered positive and significant association with dry matter accumulation, number of effective tillers and straw yield; filled grains per panicle with LAI at 50% flowering, dry matter accumulation and 1000 grain weight; 1000 grain weight with straw yield, whereas 1000 grain weight showed negative and significant association with grain yield (Table 3 and Figure 3). Total tiller density, LAI at 50% flowering and dry matter accumulation exhibited positive non-significant correlation with grain yield. There was non-significant negative correlation between plant height, number of effective tillers and filled grains per panicle with grain yield.

Among all the characters studied under path coefficient analysis, the number of total tillers per unit area had the maximum positive direct effect and test weight had maximum negative direct effect on grain yield (Table 4 and Figure 4). On the other hand, positive direct effects on grain yield were recorded in case of plant height, total tiller density, LAI at 50% flowering and dry matter accumulation, while negative direct effect on grain yield were recorded in case ofnumber of effective tillers, filled grains per panicle, 1000 grain weight and straw yield. The indirect expression of tiller density on grain yield through all the aforesaid characters were negative except LAI at 50% flowering and dry matter accumulation. The indirect effect expression of test weight on grain yield through all the aforesaid characters were positive except number of effective tillers, filled grains per panicle and straw yield.

Correlation and Path analysis studies of puddled transplanted rice (PTR)

Under puddled transplanting rice, total tiller registered positive and significant association with number of effective tillers and filled grains per panicle; number of effective tillers with filled grains per panicle and straw yield; filled grains per panicle with 1000 grain weight; 1000 grain weight with grain yield (Table 5 and Figure 5). Except LAI at 50% flowering all the aforesaid characters had positive association with grain yield, however, the correlation was statistically non-significant.

Among all the characters studied under path coefficient analysis, straw yield had the maximum positive direct effect and number of effective tillers had maximum negative direct effect on grain yield (Table 6 and Figure 6). On the other hand positive direct effect on grain yield were recorded in case of total tiller, dry matter accumulation, filled grains per panicle, test weight and straw yield, while negative direct effect on grain yield were recorded in case of plant height, LAI at 50% flowering and number of effective tillers. The indirect expression of total tiller density and 1000 grain weight on grain yield through all the aforesaid characters were negative except plant height, LAI at 50% flowering and number of effective tillers. The indirect effect expression of LAI at 50% flowering on grain yield through all the aforesaid characters were positive except number of effective tillers.

Under direct seeded rice and non-puddled transplanting rice, total tiller density expressed maximum positive, but non-significant association with grain yield, however under puddled transplanted rice 1000 grain weight exhibited maximum positive and significant association with grain yield. There existed maximum negative association of dry matter accumulation at PM and LAI at 50% flowering under direct seeded rice and puddled transplanted, respectively with grain yield. However under non-puddled transplanted rice, 1000 grain weight expressed the maximum negative and significant association with grain yield.

Under all the establishment methods, total tiller density had positive and significant association with number of effective tillers (Table 1 to 6 and Fig. 1 to 6). Dry matter accumulation had negative association with grain yield under direct seeded rice due to accumulation in the stem before grain filling and poor translocation of photosynthates from the source to the sink. Similar finding was obtained by Chen *et al.* (2012) [2]. Total tiller density, 1000 grain weight and filled grains per panicle contributed the maximum to grain yield under direct seeded rice, non-puddled transplanted rice and puddled transplanted rice, respectively. These results were in agreement with that of Roy *et al.* (1995) [7], Reddy *et al.* (1997) [6], Suerk (2003) [9] and Kato *et al.* (2008) [5].

Table 1: Correlation matrix among various yield attributing and ancillary characters with grain yield under direct seeded rice (DSR).

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Plant height	1	-0.0092	0.2801	-0.1686	-0.2187	-0.1294	0.1251	0.256	0.1351
2	Total tiller		1	0.0510	0.0447	0.3394**	0.2033	0.1591	-0.2569	0.1354
3	LAI at 50% flowering			1	-0.1730	0.1493	0.3557**	0.1822	-0.1065	0.1324
4	Dry matter at PM				1	0.0429	0.0144	0.1510	0.1190	-0.1588
5	EBT m^{-2}					1	0.3344**	0.1522	-0.2806	0.0440
6	Fill grain p^{-1}						1	0.3341**	-0.2737	-0.011
7	1000 g. wt							1	0.1406	-0.0008
8	Straw yield								1	0.1156
9	Grain yield									1

**Significant at alpha=5%

Table 2: Path analysis matrix (direct and indirect effect) of yield attributing and ancillary characters on grain yield under direct seeded rice (DSR)

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1	Plant height	0.0420	-0.0017	0.0331	0.0263	-0.0118	0.0032	-0.0076	0.0512	0.1346
2	Total tiller	-0.0004	0.1850	0.0060	-0.0070	0.0183	-0.0051	-0.0097	-0.0514	0.1358
3	LAI at 50% flowering	0.0118	0.0094	0.1180	0.0270	0.0081	-0.0089	-0.0111	-0.0213	0.1329
4	Dry matter at PM	-0.0071	0.0083	-0.0204	-0.1560	0.0023	-0.0004	-0.0092	0.0238	-0.1587
5	EBT m^{-2}	-0.0092	0.0628	0.0176	-0.0067	0.0540	-0.0084	-0.0093	-0.0561	0.0448
6	Fill grain p^{-1}	-0.0054	0.0376	0.0420	-0.0022	0.0181	-0.0250	-0.0204	-0.0547	-0.0102
7	1000 g. wt	0.0053	0.0294	0.0215	-0.0236	0.0082	-0.0084	-0.0610	0.0281	-0.0004
8	Straw yield	0.0108	-0.0475	-0.0126	-0.0186	-0.0152	0.0068	-0.0086	0.2000	0.1152

Residual: 0.9503, Bold figure denotes direct effect

Table 3: Correlation matrix among various yield attributing and ancillary characters with grain yield under non-puddled transplanted rice (NPTR)

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Plant height	1	-0.0039	-0.1208	0.1652	-0.0421	0.0151	0.1409	0.2217	-0.0403
2	Total tiller		1	0.1492	0.3446**	0.362**	0.2871	0.2412	0.4325**	0.1559
3	LAI at 50% flowering			1	0.2376	0.0923	0.3165**	0.1772	-0.0267	0.153
4	Dry matter at PM				1	0.2371	0.3027**	0.0571	0.1644	0.1066
5	EBT m^{-2}					1	0.1768	0.1774	0.1934	-0.0382
6	Fill grain p^{-1}						1	0.4214**	0.2138	-0.1547
7	1000 g. wt							1	0.398**	-0.3969**
8	Straw yield								1	-0.1032
9	Grain yield									1

**Significant at alpha=5%

Table 4: Path analysis matrix (direct and indirect effect) of yield attributing and ancillary characters on grain yield under non-puddled transplanted rice (NPTR)

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1	Plant height	0.0520	-0.0011	-0.0280	0.0038	0.0027	-0.0017	-0.0631	-0.0047	-0.0402
2	Total tiller	-0.0002	0.2860	0.0346	0.0079	-0.0228	-0.0324	-0.1081	-0.0091	0.1559
3	LAI at 50% flowering	-0.0063	0.0427	0.2320	0.0055	-0.0058	-0.0358	-0.0794	0.0006	0.1535
4	Dry matter at PM	0.0086	0.0986	0.0551	0.0230	-0.0149	-0.0342	-0.0256	-0.0035	0.1071

5	EBT m^{-2}	-0.0022	0.1035	0.0214	0.0055	-0.0630	-0.0200	-0.0795	-0.0041	-0.0383
6	Fill grain p^{-1}	0.0008	0.0821	0.0734	0.0070	-0.0111	-0.1130	-0.1888	-0.0045	-0.1541
7	1000 g. wt	0.0073	0.0690	0.0411	0.0013	-0.0112	-0.0476	-0.4480	-0.0084	-0.3964
8	Straw yield	0.0115	0.1237	-0.0062	0.0038	-0.0122	-0.0242	-0.1783	-0.0210	-0.1028

Residual: 0.8484, Bold figure denotes direct effect

Table 5: Correlation matrix among various yield attributing and ancillary characters with grain yield under puddled transplanted rice (PTR)

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Plant height	1	0.1385	-0.0697	0.0595	0.0641	0.2348	0.2446	-0.0428	0.0726
2	Total tiller		1	0.192	0.2377	0.4664**	0.5716**	0.2789	0.0984	0.2826
3	LAI at 50% flowering			1	0.1287	0.0909	0.096	0.0432	0.0194	-0.0074
4	Dry matter at PM				1	0.2648	0.2866	0.2831	0.0486	0.1509
5	EBT m^{-2}					1	0.464**	0.2114	0.3463**	0.1576
6	Fill grain p^{-1}						1	0.3905**	0.1496	0.2639
7	1000 g. wt							1	0.1326	0.3249**
8	Straw yield								1	0.2792
9	Grain yield									1

**Significant at alpha=5%

Table 6: Path analysis matrix (direct and indirect effect) of yield attributing and ancillary characters on grain yield under puddled transplanted rice (PTR)

		Character								
Sl. No.	**Character**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1	Plant height	-0.0160	0.0298	0.0046	0.0027	-0.0073	0.0155	0.0548	-0.0110	0.0731
2	Total tiller	-0.0022	0.2150	-0.0127	0.0107	-0.0532	0.0377	0.0625	0.0252	0.2830
3	LAI at 50% flowering	0.0011	0.0413	-0.0660	0.0058	-0.0104	0.0063	0.0097	0.0050	-0.0072
4	Dry matter at PM	-0.0010	0.0511	-0.0085	0.0450	-0.0302	0.0189	0.0634	0.0124	0.1512
5	EBT m^{-2}	-0.0010	0.1003	-0.0060	0.0119	-0.1140	0.0306	0.0474	0.0887	0.1578
6	Fill grain p^{-1}	-0.0038	0.1229	-0.0063	0.0129	-0.0529	0.0660	0.0875	0.0383	0.2646
7	1000 g. wt	-0.0039	0.0600	-0.0029	0.0127	-0.0241	0.0258	0.2240	0.0339	0.3256
8	Straw yield	0.0007	0.0212	-0.0013	0.0022	-0.0395	0.0099	0.0297	0.2560	0.2788

Residual: 0.8884, Bold figure denotes direct effect

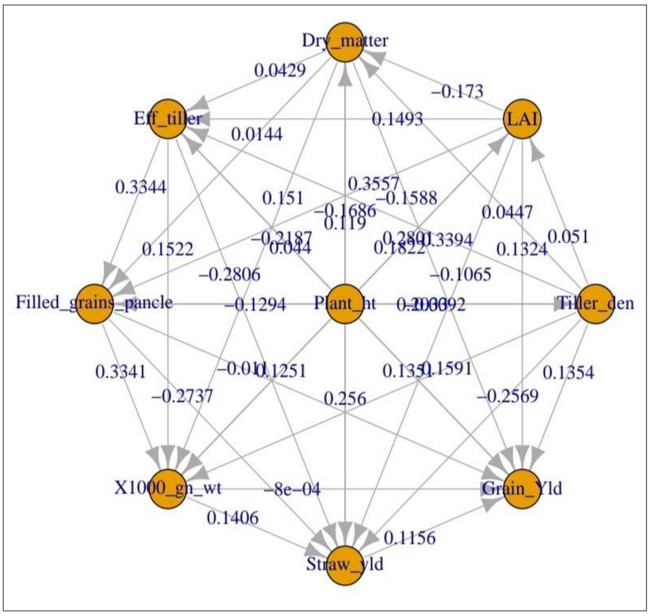

Fig 1: Correlation matrix among various yield attributing and ancillary characters with grain yield under direct seeded rice (DSR)

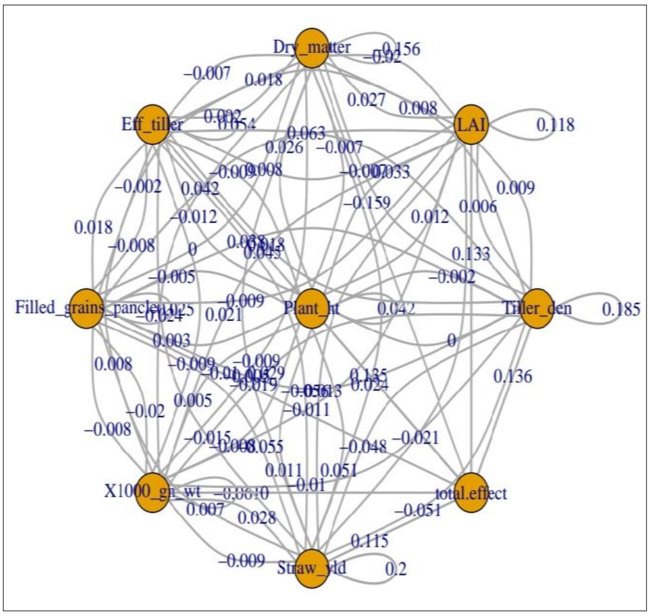

Fig 2: Phenotypic path analysis (direct and indirect effect) of yield attributing and ancillary characters on grain yield under direct seeded rice (DSR)

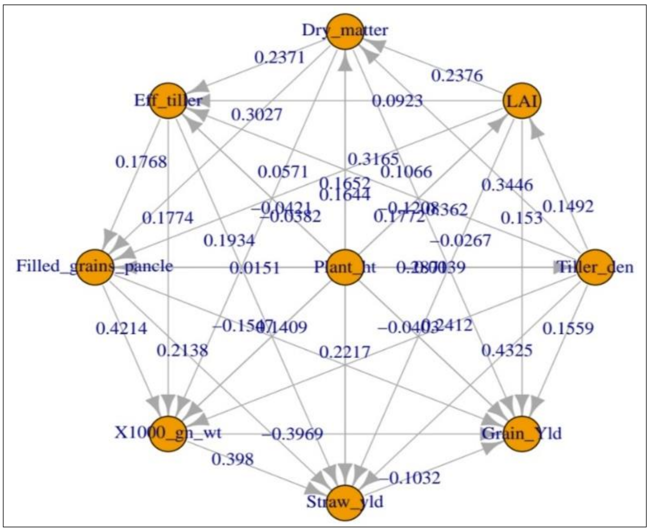

Fig 3: Correlation matrix among various yield attributing and ancillary characters with grain yield under non-puddled transplanted rice (NPTR)

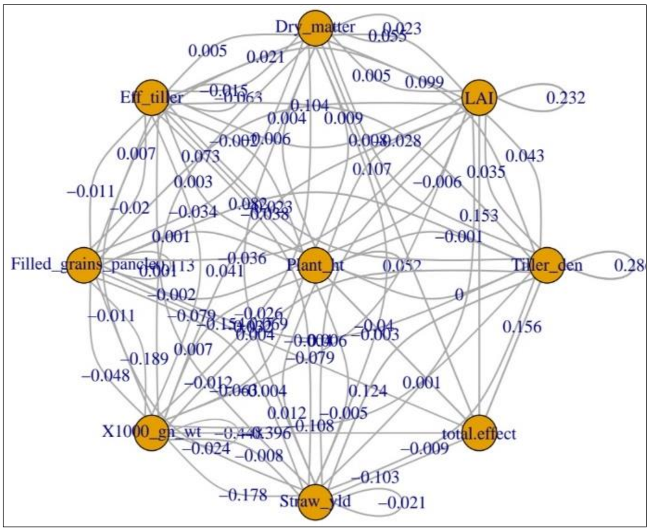

Fig 4: Phenotypic path analysis (direct and indirect effect) of yield attributing and ancillary characters on grain yield under non-puddled transplanted rice (NPTR)

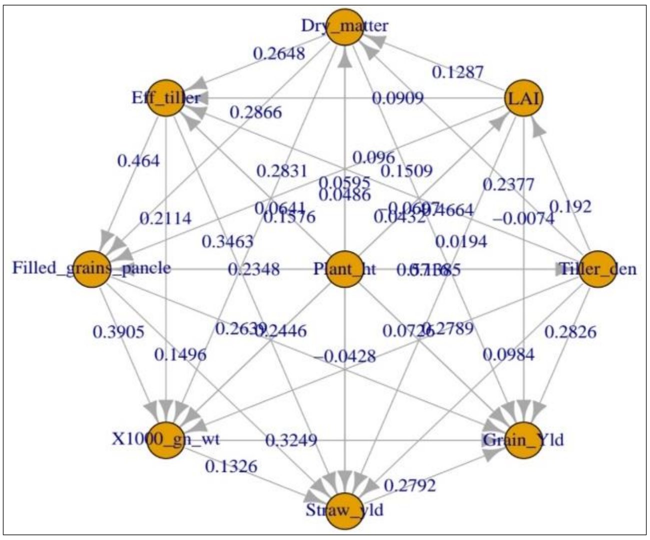

Fig 5: Correlation matrix among various yield attributing and ancillary characters with grain yield under puddled transplanted rice (PTR)

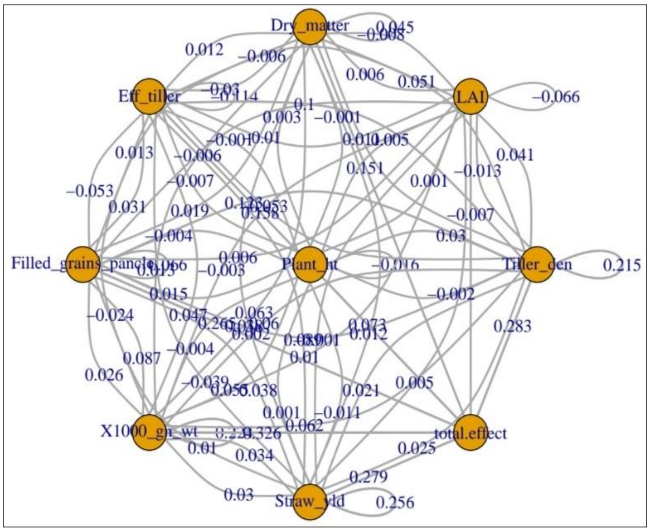

Fig 6: Phenotypic path analysis (direct and indirect effect) of yield attributing and ancillary characters on grain yield under puddled transplanted rice (PTR)

Conclusions

Both qualitative and quantitative relationship existing between grain yield and other yield attributing characters in terms of correlation and regression coefficient was studied under different rice crop establishment methods in this experiment. All the establishment methods *viz*. direct seeded rice, non-puddled transplanted rice and puddle transplanted rice showed positive and significant association of total tiller density with number of effective tillers. Dry matter accumulation had negative association with grain yield under direct seeded rice, but positive association was found under NPTR and PTR. Total tiller density, 1000 grain weight and filled grains per panicle contributed the maximum to grain yield under direct seeded rice, non-puddled transplanted rice and puddled transplanted rice, respectively.

Future scope

In Odisha many farmers raise rice crop by transplanting of seedling under puddle condition. Transplanting after puddling is associated with various constraints like late planting due to non-availability of water and labour at peak time resulting in low plant population and yield reduction. At the same time, field preparation by puddling deteriorates soil physical properties which become uncongenial for the succeeding crops. So there is need to search for alternate crop establishment methods to increase the productivity and sustainability of the system. Moreover emphasis should be given to quantify the existing relationship between the yield and yield attributing characters under different establishment methods to find out the plant characters that could serve as good yield component to improve rice productivity.

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