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# Association and Path Analysis of Yield and Component Traits of Rice under Dry Direct Seeded Condition

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**ABSTRACT: In light of climate change posing a threat to food crop production Direct seeded rice (DSR), an alternative to transplanted system of rice cultivation, is promoted when problem of low productivity is addressed. Association and Path analysis allows identification of key traits contributing to yield enhancement. This study was taken up during *Kharif* 2022 to unravel the significant associations among yield attributing traits under DSR conditions and thereby identify the promising component traits whose selection would improve yield in DSR. A total of 184 backcross inbred lines along with five checks and two parents were utilised for evaluation. Yield attributing traits such as Days to 50% flowering, Number of leaves at harvest, Number of tillers at harvest, Number of productive tillers, Plant height, Panicle length, Number of spikelets per panicle, Number of filled grains per panicle, Spikelet fertility %, Test weight and Single plant yield were recorded at harvest stage. The traits such as plant height, number of filled grains per panicle and test weight was found to have prominent influence on yield from the results of correlation and path analysis. However, a substantial residual effect observed in the path analysis suggested existence of additional factors contributing to yield variation in DSR that were not considered in this study.**

**Keywords:** Correlation, path analysis, Direct seeded rice, yield, yield attributing traits.

## INTRODUCTION

Assuring sustainability of global food security is the foremost objective in agricultural research. With a burgeoning world population and the challenges posed by climate change, preserving natural resources and enhancing the resilience of food production systems are critical imperatives. Rice being one of the most important food grain crop of the world, commands significant attention from agricultural researchers who strive to increase yield potential of rice varieties and hybrids (Hossain and Fischer 1995). However, this pursuit has been challenged with factors like climate change, decline in soil productivity, water crisis etc. Reports highlight that water scarcity and rising labor costs pose threats to conventional rice farming systems (Khokhar and Sarial 2018). Given the pressing need to increase yield efficiency while minimizing costs, alternative production systems like the System of Rice Intensification (SRI) and Direct Seeded Rice (DSR) have garnered research focus, particularly on aspects related to productivity. In this regard, the DSR system, contrary to transplanted rice (TPR) system, has gained popularity in the recent past due to its low input demanding nature, especially in terms of water and labour. The promotion of DSR stems from the imperative to shift focus from mere "land productivity" to "water productivity," aiming to maximize yield per unit of water utilized in agriculture (Kharb *et al*., 2015). DSR also combines several advantages like early crop, low methane emission from fields, feasibility to include rice cultivation with other cropping systems etc. But one of the major drawbacks of DSR is the low productivity compared to TPR (Singh *et al*., 2016; Quilloy *et al*., 2021) which underscores the importance of ongoing research efforts to optimize DSR techniques in order to enhance yield and overcome productivity limitations.

This low productivity in DSR has been attributed to the usage of rice varieties specifically bred for irrigated conditions in Direct seeded system (Sagare *et al*., 2020). Jung and McCouch (2013) emphasized that even ecotypes or varieties of a plant species adapted for different ecologies vary widely in their aerial and rhizosphere traits. Consequently, there is a growing need to develop rice varieties tailored specifically for direct-seeded ecologies to address this challenge effectively. Supportively, Sarla and Swamy (2005) reported the usefulness of *O. glaberrima* as donor parent in crop improvement of Asian rice especially for growth in adverse conditions of low resource availability. Strategies for development of DSR varieties must focus on traits that enable better survival and yielding ability of rice plants in direct seeded condition. It is also essential to recognize that relying solely on grain yield as a selection criterion may lead to inconsistent performance of genotypes, primarily due to the intricate nature of yield traits (Ratna *et al*., 2015). Additionally, low heritability of the trait has also prompted breeders to advocate indirect selection for yield in rice (Atlin, 2003). Thus, analysis of correlation among component yield traits followed by the partitioning of these correlations into direct and indirect effect as suggested by Wright (1921) is reliable for interpretation of associations among yield and its component traits (Madhukar *et al*., 2017). On account of this, the current study aimed to investigate the correlation between grain yield and its various components, analyze the direct and indirect impacts of these factors on paddy yield, and pinpoint optimal combinations to serve as selection criteria for developing high-yielding rice genotypes suitable for dry direct seeded conditions.

## MATERIALS AND METHODS

The study utilized 184 backcross inbred lines ($BC_1F_8$ generation) derived from the interspecific cross of IR64*1/*O.glaberrima* alongside parental lines and four checks. Field experiments were conducted at the ICAR-Indian Institute of Rice Research (IIRR) in Hyderabad, Telangana, during the Kharif season of 2022, employing an augmented design. The reference checks comprised Browngora, DRR Dhan 44, Sabita, Samba Mahsuri, and Sabhagidhan varieties. The dry direct seeding method was employed for sowing, involving the direct placement of rice seeds into ploughed dry soil, followed by gradual flooding irrigation. Top dressing was given with urea and murate of potash followed by need based fertilizer application and slow flooding irrigation at regular intervals. Yield attributing traits such as Days to 50% flowering (DFF), Number of leaves at harvest (NL), Number of tillers at harvest (NT), Number of productive tillers (NPT), Plant height (PHT), Panicle length (PL), Number of spikelets per panicle (NSP), Number of filled grains per panicle (NFG), Spikelet fertility % (SF), Test weight (TW) and Single plant yield (SPY) were recorded at harvest stage. Data on each trait from three plants were taken in each line or entry and average was estimated. Correlation analysis was carried out using the collected observations in R studio (version 4.3.2) based on the theory given by Pearson (1904). The statistical analysis for estimating Path coefficients as proposed by Dewey and Lu (1959) was utilised and carried out in R studio (version 4.3.2). The sorting of path coefficients into various classes based on magnitude have been followed according to Lenka and Mishra (1973).

## RESULTS AND DISCUSSION

The correlation coefficients estimated among yield and its attributing traits during *Kharif* 2022 under dry direct seeded condition for 184 backcross inbred lines (BILs) have been tabulated in Table 1. Significance in associations among these traits have been depicted as asterisk (*)sign (Fig. 1). Although DFF was found to have positive associations with NL (0.08), NPT (0.08), and NFG (0.07), significance for the positive relation was observed with NT (0.25) and NSP (0.16) only. Meanwhile, negative associations were found between DFF and PHT, PL, SF, TW, and SPY. This was parallel to the results of Madhukar *et al*. (2017) as well as Saran *et al*. (2023). The inverse associations of DFF with yield (SPY) and DFF with plant height may be beneficial as it indicates scope for selection of lines that are early flowering high yielders as well as late flowering dwarf types. Positive and significant association with NL was exhibited by NSP (0.19) and NPT (0.62) only. Meanwhile number of productive tillers NPT exhibited positive correlation with NT (0.58*), NSP (0.02) and TW (0.11) while negative relation with PHT (-0.05), NFG (-0.02), PL (-0.11), SF (-0.05) and SPY (-0.04). However, these results were unlike the findings of Demeke *et al*. (2023) who reported positive significant association between number of productive tillers and single plant yield but negative correlation between NPT and TW. NT had positive correlations with DFF (0.25*), NL (0.28), NPT (0.58), NSP (0.05), PHT (0.03) and NFG (0.01). Although the absence of correlation between NT and SF was against the reports of Saran *et al*. (2023), the association of NT with NFG coincided with their results. Meanwhile, PHT possessed positive relation with most traits such as NFG (0.23*), NSP (0.28*), PL (0.73*) and SPY (0.24*). Similar association of PHT with SPY was noted in the research of Khan *et al*. (2022) indicating a potential equilibrium between vegetative and reproductive growth in rice. Lan *et al*. (2023) proposed extreme deviations in plant height could detrimentally impact rice yields, indicating the necessity for finding an optimal balance. There may also exist such balancing interplays between PHT and NPT as well as PHT and TW which could be the reason for negative association observed between them. Taller plants tend to direct photosynthates for growth rather than in developing productive tillers or grain formation. Hence it may be agreed that breeding for semi-tall varieties over dwarf varieties is more advantageous as observed in the findings of Parimala *et al*. (2016). Similarly, NFG had negative correlation with NPT (-0.02) and TW (-0.18) which also points out the aspect of dry matter partitioning, whereby the number of filled grains in a panicle may be increased at the expense of average weight of a single grain. But DFF (0.07), NL (0.14), NT (0.01), PHT (0.23*), NSP (0.86*), PL (0.23*), SF (0.64*) and SPY (0.22*) exhibited positive relation with NFG, making it an important trait in selection of yield improvement (Parimala *et al*., 2016; Madhukar *et al*., 2017; Dameke *et al*., 2023; Saran *et al*., 2023). However, this was against the opinions of Surek and Beser (2003); Bagheri *et al*. (2011); Venkata Lakshmi *et al*. (2014). The significantly negative relation of number of spikelets per panicle NSP with TW (-0.22*) accompanied by its positive association with PL (0.29*) and NFG (0.86*) reinforces the potential equilibrium in biomass allocation. It highlights the possibility of long panicles with higher number of spikelets per panicle eventually resulting in high number of filled but small sized grains. Positive association of NSP with PL and NFG were also given by earlier researchers like Rajamadhan *et al*. (2011); Adithya and Anuradha (2013); Singh *et al*. (2013); Madhukar *et al*. (2017). Except for NT (0.05) and NPT (0.02) all other traits like DFF, NL, PHT, SF and SPY exhibited significantly positive relation with NSP. When PL had positive correlation with traits such as PHT (0.73*), NFG (0.23*), NSP (0.29*), and SPY (0.18*), it exhibited negative relation with DFF (-0.03), NPT (-0.11), NT (-0.02) and TW (-0.10). Meanwhile SF had positive correlations with NFG (0.64*), NSP (0.20*), PL (0.05) and SPY (0.26*). The positive correlation of SF with PL and NFG was aligning with results of Parimala *et al*. (2016) whereas similar relation of SF with SPY was reported by Haider *et al*. (2012); Singh *et al*. (2013); Chandan Kumar and Nilanjaya (2014). Similar to SF, test weight also did not exhibit any correlation with NT though most traits were negatively associated with TW, except NPT (0.11) and SPY (0.22*). The negative association of TW with NSP (-0.22) and NFG (-0.18) was however, significant. It may be noted that when NL and NT had no correlation with single plant yield, NPT had negative association (-0.04). Meanwhile all other traits [PHT (0.24), NFG (0.22), PL (0.18), SF (0.26), TW (0.22)] had positive significant relation with SPY, except NSP (0.08) which was positive but non-significant. The results were in agreement with Hairmansis *et al.* (2010) for NFG while in conformity with Yadav *et al*. (2010); Akhtar *et al.* (2011); Yadav *et al*. (2011); Seyoum *et al*. (2012); Venkata Lakshmi *et al*. (2014) for PHT. Thus, the study disclosed plant height, number of filled grains per panicle, panicle length, spikelet fertility and test weight as major traits significantly contributing to plant yield based on correlation analysis. Panicle architecture and plant stature has been concluded to be important for yield in DSR conditions as per reports of Madhukar *et al*. (2017).

The results of path analysis conducted for same data recorded on 184 lines have been tabulated in Table 2, to partition the correlation into direct effects, indirect effects and sort them into classes. As expected, and observed in the studies of Parte *et al*. (2022) and Saran *et al*. (2023), DFF had a negative direct effect (-0.0361) on yield. While it affected yield indirectly and positively through NL, NT, NFG and SF negligibly. Meanwhile, NL effected yield directly (0.0254) as well as indirectly through NT, PHT and PL but the effect was negligible. But it had low indirect positive effect through NFG (0.1561). Although NPT had negative (-0.0872) negligible direct effect on yield as observed in the research of Parte *et al*. (2022), its indirect effects through NL, NT, SF and TW were positive and negligible. The effect of NT on yield was found positive but negligible directly (0.0774) as against the reports of Parte *et al*. (2022) and Saran *et al*. (2023). But indirectly through NL, PHT and NFG, it influenced yield positively. The traits such as PHT (0.2141) and NFG (1.1152) had moderate and very high positive direct effect on yield respectively. Indirectly these traits affected yield through NL, NT, NPT and PL positively and negligibly. Nonetheless there were also findings of plant height with negative direct and indirect effects on yield (Panwar, 2006; Himaja *et al*., 2022). When considering the indirect effects on yield, plant height influences yield through its impact on days to flowering (DFF). Additionally, the number of filled grains (NFG) positively affects yield, partly through its indirect association with plant height. Despite the high negative direct effect of NSP on yield (-0.8344), it had high positive indirect effect on yield through NFG (0.9591). A very high negative direct effect of NSP on SPY was also revealed by Seyoum *et al*. (2012) in their study portraying it as a much less preferred trait for direct selection as NSP effected yield positively but negligibly through NL, NT and PHT. Panicle length possessed positive but negligible direct effect (0.0380) on yield. However, it had positive indirect effects on yield which was negligible through DFF, NL, NPT, low through PHT and moderate through NFG. Like NSP, spikelet fertility also exhibited high negative direct influence on yield. Inspite of this, it influenced yield highly and positively (0.7137) but indirectly through NFG as stated by Parte *et al*. (2022). Test weight had moderate positive impact on yield directly (0.2571) as seen in the research of Madhukar *et al*. (2017) while through DFF, NSP and SF it affected yield positively and indirectly. Thus, in the analysis conducted, it was revealed that several traits like number of leaves, number of tillers, plant height, number of filled grains per panicle, panicle length and test weight were direct determinant of yield in DSR conditions. However, only three of these traits *viz*., plant height, number of filled grains per panicle and test weight had significant direct effect on yield. Therefore, these three traits are deemed to be the most influential factors for selection in order to enhance yield in DSR conditions.

**Table 1: Pearson Correlation coefficients for yield traits under dry direct seeded rice condition.**

| | DFF | NL | NPT | NT | PHT | NFG | NSP | PL | SF | TW | SPY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFF | 1.00 | | | | | | | | | | |
| NL | 0.08 | 1.00 | | | | | | | | | |
| NPT | 0.08 | 0.62 | 1.00 | | | | | | | | |
| NT | 0.25 | 0.28 | 0.58 | 1.00 | | | | | | | |
| PHT | -0.13 | 0.10 | -0.05 | 0.03 | 1.00 | | | | | | |
| NFG | 0.07 | 0.14 | -0.02 | 0.01 | 0.23 | 1.00 | | | | | |
| NSP | 0.16 | 0.19 | 0.02 | 0.05 | 0.28 | 0.86 | 1.00 | | | | |
| PL | -0.03 | 0.11 | -0.11 | -0.02 | 0.73 | 0.23 | 0.29 | 1.00 | | | |
| SF | -0.08 | 0.01 | -0.05 | 0.00 | 0.06 | 0.64 | 0.20 | 0.05 | 1.00 | | |
| TW | -0.07 | -0.04 | 0.11 | 0.00 | -0.08 | -0.18 | -0.22 | -0.10 | -0.03 | 1.00 | |
| SPY | -0.10 | 0.00 | -0.04 | 0.00 | 0.24 | 0.22 | 0.08 | 0.18 | 0.26 | 0.22 | 1.00 |

DFF -Days to 50% flowering, NL- Number of leaves at harvest, NT- Number of leaves, NPT- Number of productive tillers, PHT – Plant height, NSP- Number of spikelets per panicle, NFG- Number of filled grains per panicle, PL- Panicle length, SF- Spikelet fertility, TW -Test weight, SPY- Single plant yield

**Table 2: Direct (diagonal) and Indirect effect of component yield traits on single plant yield under dry direct seeded rice condition.**

| | DFF | NL | NPT | NT | PHT | NFG | NSP | PL | SF | TW |
|---|---|---|---|---|---|---|---|---|---|---|
| DFF | **-0.0361** | 0.0020 | -0.0070 | 0.0194 | -0.0278 | 0.0781 | -0.1335 | -0.0011 | 0.0241 | -0.0180 |
| NL | -0.0029 | **0.0254** | -0.0541 | 0.0217 | 0.0214 | 0.1561 | -0.1585 | 0.0042 | -0.0030 | -0.0103 |
| NPT | -0.0029 | 0.0158 | **-0.0872** | 0.0449 | -0.0107 | -0.0223 | -0.0167 | -0.0042 | 0.0151 | 0.0283 |
| NT | -0.0090 | 0.0071 | -0.0506 | **0.0774** | 0.0064 | 0.0112 | -0.0417 | -0.0008 | 0.0000 | 0.0000 |
| PHT | 0.0047 | 0.0025 | 0.0044 | 0.0023 | **0.2141** | 0.2565 | -0.2336 | 0.0278 | -0.0181 | -0.0206 |
| NFG | -0.0025 | 0.0036 | 0.0017 | 0.0008 | 0.0492 | **1.1152** | -0.7176 | 0.0087 | -0.1929 | -0.0463 |
| NSP | -0.0058 | 0.0048 | -0.0017 | 0.0039 | 0.0599 | 0.9591 | **-0.8344** | 0.0110 | -0.0603 | -0.0566 |
| PL | 0.0011 | 0.0028 | 0.0096 | -0.0015 | 0.1563 | 0.2565 | -0.2420 | **0.0380** | -0.0151 | -0.0257 |
| SF | 0.0029 | 0.0003 | 0.0044 | 0.0000 | 0.0128 | 0.7137 | -0.1669 | 0.0019 | **-0.3014** | -0.0077 |
| TW | 0.0025 | -0.0010 | -0.0096 | 0.0000 | -0.0171 | -0.2007 | 0.1836 | -0.0038 | 0.0090 | **0.2571** |

Residual effect = 0.777

DFF -Days to 50% flowering, NL- Number of leaves at harvest, NT- Number of leaves, NPT- Number of productive tillers, PHT – Plant height, NSP- Number of spikelets per panicle, NFG- Number of filled grains per panicle, PL- Panicle length, SF- Spikelet fertility, TW -Test weight

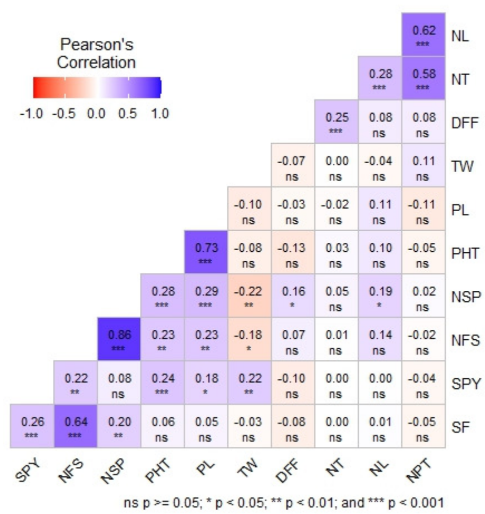


**Fig. 1.** Significance in correlations among yield traits under dry direct seeded condition.

## CONCLUSIONS

Thus, combining the results of correlation and path analysis, the study concluded that in direct seeded condition, component traits such as plant height, number of filled grains per panicle and test weight had profound role in determining yield. Selecting these traits directly may help in improving yield under DSR. Indirect selection for number of leaves at harvest, number of tillers at harvest and panicle length may also prove to be effective in improving yield. Nevertheless, it may be noted that the path analysis had high residual effect (0.777) meaning that some other characters that have not been studied here needs inclusion to account fully for explaining variation in single plant yield.

## FUTURE SCOPE

Validation of these results across seasons and locations may ensure accuracy of these conclusions. In summary, this study provides valuable insights into the associations among yield-related traits in DSR, laying a foundation for future research and breeding endeavours aimed at bolstering the productivity and resilience of rice cultivation in response to climate change.

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**Conflict of Interest.** None.

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