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CORRELATION AND REGRESSION ANALYSIS OF YIELD ATTRIBUTES IN RICE (*Oryza sativa* L.) AND LENTIL (*Lens culinaris* Medik.) UNDER PHOSPHORUS AND ZINC FERTILIZATION IN A RICE-LENTIL CROPPING SYSTEM

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ABSTRACT

A field experiment was conducted during the *kharif* and *rabi* seasons of 2018-19 and 2019-20 at the Central Research Farm, Gayeshpur, Nadia, West Bengal, under Bidhan Chandra Krishi Viswavidyalaya, to study the association among yield-attributing traits of rice and lentil under different phosphorus and zinc levels in a rice-lentil cropping system. The experiment was laid out in a split plot design with four phosphorus levels (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) in main plots and three zinc levels (0, 5 and 10 kg Zn ha^{-1}) in subplots with three replications. In rice, panicle weight (r = 0.951), filled grains panicle^{-1} (r = 0.951), 1000-grain weight (r = 0.951), effective tillers m^{-2} (r = 0.906) and harvest index (r = 0.910) showed strong positive correlations with grain yield, while chaff percentage showed a strong negative correlation (r = -0.972). Regression analysis revealed high coefficients of determination for grain yield with chaff percentage (R^2 = 0.944), panicle weight (R^2 = 0.904), filled grains panicle^{-1} (R^2 = 0.904) and 1000-grain weight (R^2 = 0.903). In lentil, pods plant^{-1} showed the highest positive correlation with seed yield (r = 0.974), followed by harvest index (r = 0.923), test weight (r = 0.918) and seeds pod^{-1} (r = 0.828). Regression analysis indicated R^2 values of 0.949, 0.851, 0.842 and 0.685 for pods plant^{-1}, harvest index, test weight and seeds pod^{-1} with seed yield, respectively. Balanced phosphorus and zinc nutrition significantly enhanced yield-attributing characters and productivity in both crops.
***Keywords*:** Correlation, lentil, phosphorus, regression, rice, rice-lentil cropping system, yield attributes, zinc

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops, serving as the staple food for more than half of the global population (FAO 2022). In India, rice occupies a predominant position in food security, agricultural economy and livelihood. Lentil (*Lens culinaris* Medik.) is a nutritionally important pulse crop rich in protein, minerals and vitamins, and contributes significantly to soil fertility through biological nitrogen fixation (Erskine *et al*., 2009). The rice-lentil cropping system is widely practised in eastern and central India owing to its higher productivity, profitability and sustainability (Singh *et al*., 2001).

Among essential plant nutrients, phosphorus (P) and zinc (Zn) are critically important for crop growth and productivity. Phosphorus participates in energy transfer, root development, flowering, seed formation and photosynthate translocation (Marschner 2012). Zinc is required for enzyme activation, chlorophyll synthesis, auxin production and carbohydrate metabolism; its deficiency is increasingly common in intensively cultivated soils under rice-based systems (Alloway, 2009). Balanced P and Zn fertilization of rice under a rice-wheat cropping system significantly improved yield components and harvest index (Amanullah and Inamullah, 2016a); and their residual effects enhanced the productivity of the succeeding crop (Amanullah and Inamullah, 2016b).

Yield is a complex quantitative character governed by several interrelated traits. Correlation analysis quantifies the degree and direction of association among characters, while regression analysis measures the contribution of independent variables to yield (Gomez and Gomez, 1984). In rice, yield is principally influenced by effective tiller number, panicle characteristics, grain filling and 1000-grain weight; in lentil, pods plant^{-1}, seeds pod^{-1} and seed weight are the principal determinants (Erskine *et al*., 2009). Alkahtani *et al*. 2020 demonstrated that phosphorus and zinc fertilization significantly improved the productivity and profitability of rice cultivars under a rice-wheat system. Despite this, information on correlation and regression relationships among yield-attributing traits under varying P and Zn levels in a rice-lentil cropping system in the lower Indo-Gangetic Plain is limited. The present investigation was therefore undertaken to study these associations and identify the key contributors to grain and seed yield under different phosphorus and zinc levels.

Materials and Methods

A field experiment was conducted during the *kharif* and *rabi* seasons of 2018-19 and 2019-20 at the Central Research Farm, Gayeshpur, Nadia, West Bengal (22°55′N, 88°32′E; 9.75 m) above sea leavel under Bidhan Chandra Krishi Viswavidyalaya. The experiment was laid out in a split plot design (SPD) with three replications. Four phosphorus levels P_0 (0 kg P_2O_5 ha^{-1}), P_{20} (20 kg P_2O_5 ha^{-1}), P_{40} (40 kg P_2O_5 ha^{-1}) and P_{60} (60 kg P_2O_5 ha^{-1}) were comprised in the main plots and three zinc levels i.e. Zn_0 (0 kg Zn ha^{-1}), Zn_5 (5 kg Zn ha^{-1}) and Zn_{10} (10 kg Zn ha^{-1}) was arranged in the subplots. The soil was sandy clay loam in texture with pH 7.10, organic carbon 0.56%, available phosphorus 33.40 kg ha^{-1} and available zinc 1.65 mg kg^{-1} (Jackson 1973). Rice variety 'Rajendra Bhagwati' was grown during the *kharif* season, followed by lentil variety 'WBL 77 (Moitree)' under residual fertility during the *rabi* season. Recommended agronomic practices were uniformly applied across all treatments. Observations on effective tillers m^{-2}, panicle length (cm), panicle weight (g), filled grains panicle^{-1}, chaff percentage (%), 1000-grain weight (g), straw yield (kg ha^{-1}), harvest index (%) and grain yield (kg ha^{-1}) were recorded for rice and pod length (cm), pods plant^{-1}, seeds pod^{-1}, test weight (g), stover yield (kg ha^{-1}), harvest index (%) and seed yield (kg ha^{-1}) for lentil from five randomly selected plants per subplot. Correlation and regression analyses followed procedures described by Gomez and Gomez (1984), with significance assessed at $p < 0.05$ and $p < 0.01$ using Fisher and Yates (1963) statistical tables.

Results and Discussion

Correlation analysis of yield-attributing traits of rice

Pearson's correlation analysis was performed among major agronomic traits affecting grain yield of rice (Table 1). Effective tillers m^{-2} showed a strong positive correlation with straw yield (r = 0.994) and grain yield (r = 0.906), confirming that a greater number of productive tillers directly contributes to biomass and grain productivity. Amanullah and Inamullah (2016a) similarly reported that phosphorus and zinc fertilization enhanced effective tillers and dry matter accumulation in rice, improving grain yield under a rice-wheat cropping system in northwestern Pakistan. Panicle weight showed a high positive correlation with grain yield (r = 0.951), filled grains panicle^{-1} (r = 0.967) and 1000-grain weight (r = 0.961). Filled grains per panicle demonstrated an exceptionally high correlation with 1000-grain weight (r = 0.984), indicating that improved grain filling directly enhances individual grain weight and ultimately yield. Venugopalan *et al*. (2021), working with lentil under residual soil moisture in Eastern India, the companion crop in this system emphasized the close link between nutrient management and reproductive performance of legumes grown in rice fallows.

Chaff percentage showed a strong negative correlation with grain yield (r = -0.972), and a high coefficient of determination (R^2 = 0.944), indicating that spikelet sterility is the single most important negative driver of rice grain yield. Higher spikelet fertility under balanced P and Zn application was consistent with the findings of Alkahtani *et al*. 2020 who reported significantly improved productivity and reduced unfilled spikelets under 80-120 kg P ha^{-1} combined with 10-15 kg Zn ha^{-1}. Harvest index showed a strong positive correlation with grain yield (r = 0.910), underscoring efficient assimilate partitioning as a key yield driver. Amanullah and Inamullah (2016a) demonstrated that higher P and Zn rates significantly increased harvest index in both fine and coarse rice genotypes by enhancing dry matter accumulation and panicle-directed partitioning.

Regression analysis of grain yield with yield-attributing traits of rice

Regression analysis was performed between grain yield and the four most important yield-attributing traits. A strong negative linear relationship was found between chaff percentage and grain yield (R^2 = 0.944; Fig. 1), confirming spikelet sterility as the single most important yield-reducing trait in rice. Positive and significant linear relationships were obtained for panicle weight (R^2 = 0.904; Fig. 2), filled grains panicle^{-1} (R^2 = 0.904; Fig. 3) and 1000-grain weight (R^2 = 0.903; Fig. 4) with grain yield. These high R^2 values confirm that these traits are reliable predictors of rice grain yield. Comparable results were reported by Amanullah and Inamullah (2016a), who found that phosphorus and zinc fertilization significantly improved panicle dry matter partitioning and yield components in rice genotypes. The high coefficients of determination observed in the present study suggest that management strategies improving grain filling and reducing chaff formation can substantially increase rice productivity in rice-lentil cropping systems.

Correlation analysis of yield-attributing traits of lentil

Correlation analysis was performed among key agronomic traits influencing seed yield of lentil (Table 2). Pods per plant showed the highest positive correlation with seed yield (r = 0.974), confirming it as the most critical yield determinant in lentil. This is consistent with the findings of Sarkar *et al*. (2021), who studied lentil cv. WBL 77 (the same variety used in the present experiment) in coastal West Bengal and found grain yield to be strongly dependent on pod set, which was in turn sensitive to soil moisture and temperature during the reproductive phase. Test weight (r = 0.918) and harvest index (r = 0.923) also showed strong positive correlations with seed yield, indicating that both seed size and biomass allocation efficiency are important for high lentil productivity. Seeds pod^{-1} showed a significant positive correlation (r = 0.828), further confirming the importance of seed development per pod for yield. Pod length showed a moderate but significant correlation with seed yield (r = 0.675), while stover yield showed a weaker relationship (r = 0.673). Alkahtani *et al*. 2020 reported that phosphorus and zinc fertilization improved yield components in rice under a cereal-based system; the present study extends this principle to lentil under residual P and Zn effects in a rice–lentil cropping system.

Regression analysis of seed yield with yield-attributing traits of lentil

Regression analysis revealed a strong positive linear relationship between pods per plant and seed yield (R^2 = 0.949; Fig. 5), confirming that pod number is the primary determinant of lentil seed yield. Adequate phosphorus supply has been shown to enhance flowering and pod set in legumes (Marschner 2012), and improved pod development under balanced P and Zn nutrition is consistent with the residual effects of higher P levels on the succeeding crop, as demonstrated by Amanullah and Inamullah (2016b) in a rice-wheat system. Positive significant linear relationships were found between harvest index and seed yield (R^2 = 0.851; Fig. 6), test weight and seed yield (R^2 = 0.842; Fig. 7) and seeds pod^{-1} and seed yield (R^2 = 0.685; Fig. 8). These results confirm that seed number and seed size are complementary determinants of lentil yield. The high predictive power of pods per plant and harvest index observed in the present study is consistent with the findings of Sarkar *et al*. (2021), who identified pod formation and efficient biomass utilization as key yield drivers in lentil under varied agroclimatic conditions in West Bengal. Singh *et al*. (2001) reported that integrated nutrient management significantly improved yield-attributing characters and seed yield in lentil within a rice–lentil cropping system in eastern India, providing further context for the improvements in yield traits observed in the present experiment.

Conclusion

Correlation and regression analyses confirmed that panicle weight, filled grains per panicle, 1000-grain weight, effective tillers m^{-2} and harvest index were the major determinants of grain yield in rice, while pods per plant, harvest index, test weight and seeds pod^{-1} were the most important contributors to seed yield in lentil under phosphorus and zinc fertilization in a rice-lentil cropping system. These characters can serve as effective selection criteria and management indicators for improving crop productivity. Phosphorus at 40-60 kg P_2O_5 ha^{-1} combined with zinc at 5-10 kg Zn ha^{-1} optimized yield-attributing characters in both crops; the residual effects of P and Zn applied to rice on succeeding lentil merit further investigation under diverse agro-ecological conditions of eastern India.

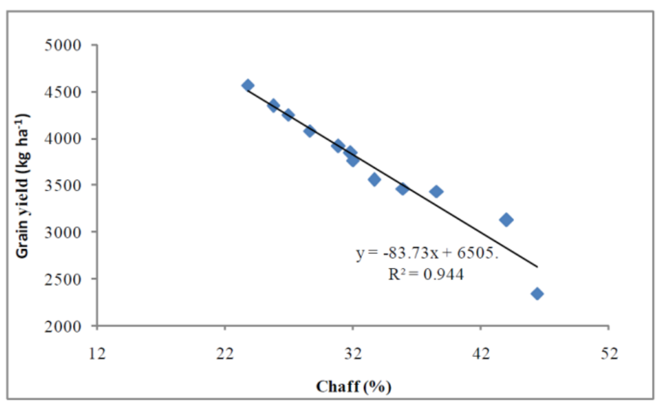

Fig. 1: Simple linear regression between chaff (%) and grain yield (kg ha^{-1}) on rice of the pooled data over two experimental years (2018 and 2019)

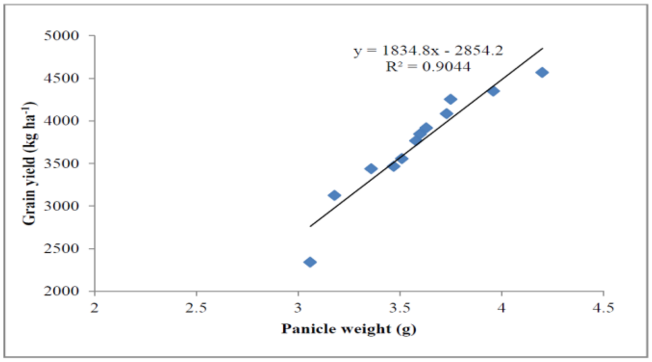

Fig. 2: Simple linear regression between panicle weight (g) and grain yield (kg ha^{-1}) on rice of the pooled data over two experimental years (2018 and 2019)

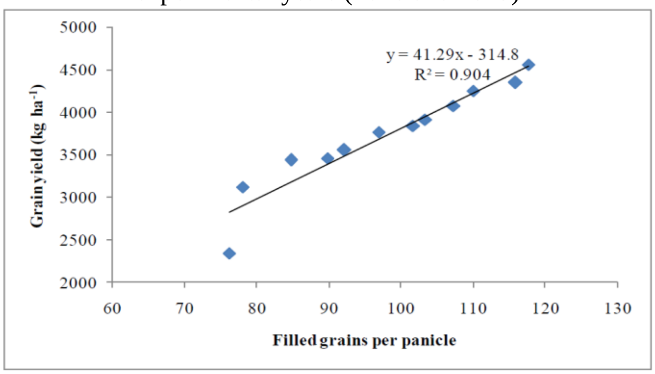

Fig. 3: Simple linear regression between filled grain per panicle weight (kg ha^{-1}) and grain yield (kg ha^{-1}) on rice of the pooled data over two experimental years (2018 and 2019).

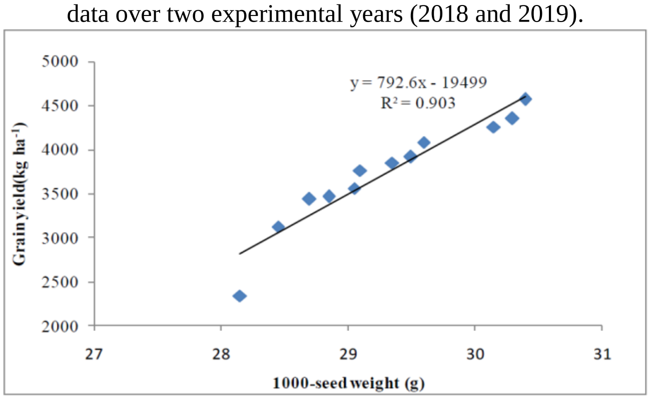

Fig. 4: Simple linear regression between 1000-seed weight (g) and grain yield (kg ha^{-1}) on rice of the pooled data over two experimental years (2018 and 2019).

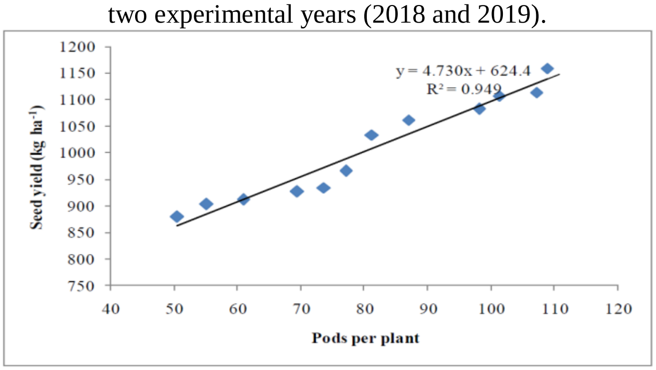

Fig. 5: Simple linear regression between pods per plant (no. plant^{-1}) and seed yield (kg ha^{-1}) on lentil of the pooled data over two experimental years (2018-19 and 2019-20).

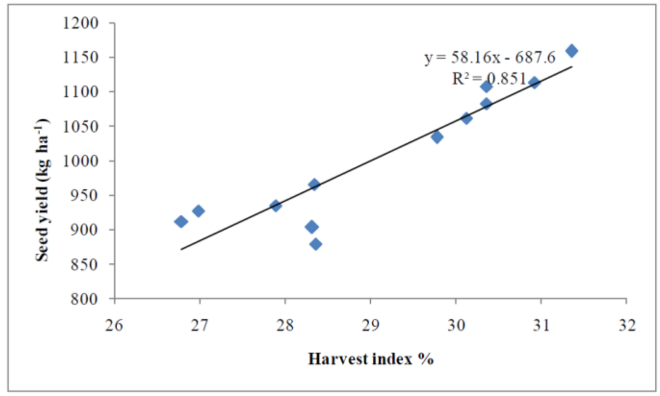

Fig. 6: Simple linear regression between harvest index (%) and seed yield (kg ha^{-1}) on lentil of the pooled data over two experimental years (2018-19 and 2019-20).

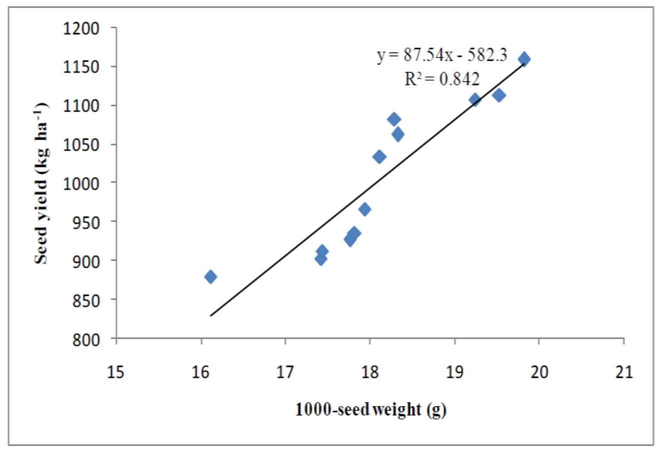

Fig. 7: Simple linear regression between 1000-seed weight (no. plant^{-1}) and seed yield (kg ha^{-1}) on lentil of the pooled data over two experimental years (2018-19 and 2019-20).

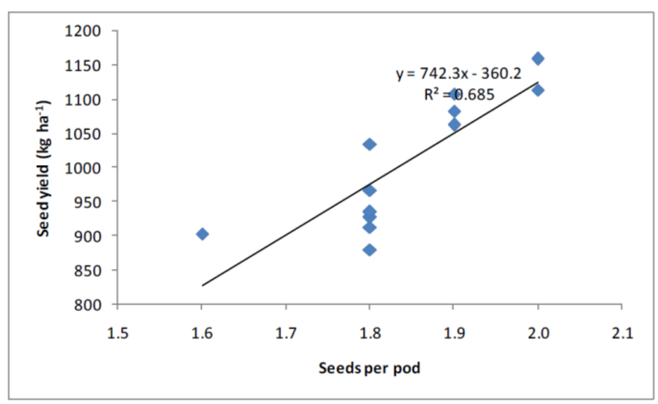

Fig. 8: Simple linear regression between seeds per pod (no. pod^{-1}) and seed yield (kg ha^{-1}) on lentil of the pooled data over two experimental years (2018-19 and 2019-20).

Table 1: Correlation matrix of key yield parameters and their relationship with grain yield of rice on pooled data over two experimental years (2018 and 2019).

	Effective tillers (m^{-2})	**Panicle length (cm)**	**Panicle weight (g)**	**Filled grains panicle^{-1}**	**Chaffs (%)**	**1000-seed weight (g)**	**Straw yield (kg ha^{-1})**	**Harvest index (%)**	**Grain yield (kg ha^{-1})**
Effective tillers (m^{-2})	1	0.874***	0.962***	0.958***	-0.914***	0.961***	0.994***	0.653*	0.906***
Panicle length (cm)	0.874***	1	0.855***	0.743**	-0.714**	0.766**	0.892***	0.434	0.717**
Panicle weight (g)	0.962***	0.855***	1	0.967***	-0.963***	0.961***	0.958***	0.764**	0.951***
Filled grains panicle^{-1}	0.958***	0.743**	0.967***	1	-0.98***	0.984***	0.946***	0.767**	0.951***
Chaffs (%)	-0.914***	-0.714**	-0.963***	-0.98***	1	-0.961***	-0.906***	-0.843***	-0.972***
1000-seed weight (g)	0.961***	0.766**	0.961***	0.984***	-0.961***	1	0.954***	0.759**	0.951***
Straw yield (kg ha^{-1})	0.994***	0.892***	0.958***	0.946***	-0.906***	0.954***	1	0.624*	0.891***
Harvest index (%)	0.653*	0.434	0.764**	0.767**	-0.843***	0.759**	0.624*	1	0.91***
Grain yield (kg ha^{-1})	0.906***	0.717**	0.951***	0.951***	-0.972***	0.951***	0.891***	0.91***	1

N.B.*** significant at 0.001 level,** significant at 0.01 level and *significant at 0.05 level

Table 2: Correlation matrix of key yield parameters and their relationship with grain yield on lentil of the pooled data over two experimental years (2018-19 and 2019-20)

	Pod length (cm)	**Pods per plant (no. plant^{-1})**	**Seeds per pod (no.)**	**Test weight (g)**	**Stover yield (kg ha^{-1})**	**Harvest index (%)**	**Seed yield (kg ha^{-1})**
Pod length (cm)	1	0.683*	0.707*	0.75**	0.39	0.646*	0.675*
Pods per plant (no. plant^{-1})	0.683*	1	0.854***	0.942***	0.744**	0.853***	0.974***
Seeds per pod (no.)	0.707*	0.854***	1	0.738**	0.65*	0.713**	0.828***
Test weight (g)	0.75**	0.942***	0.738**	1	0.78**	0.76**	0.918***
Stover yield (kg ha^{-1})	0.39	0.744**	0.65*	0.78**	1	0.337	0.673*
Harvest index (%)	0.646*	0.853***	0.713**	0.76**	0.337	1	0.923***
Seed yield (kg ha^{-1})	0.675*	0.974***	0.828***	0.918***	0.673*	0.923***	1

N.B. *** significant at 0.001 level,** significant at 0.01 level and *significant at 0.05 level

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