Results: The studies revealed that seed yield was positively correlated with, panicle weight, panicle number per plant, seeds per panicle, test weight, HD grains, Economic yield, Biological yield, Grain Harvest Index under higher iron condition. In the other study, the application of 200 ppm of $MnSO_4$ supplemented with aqueous bay leaf extract (10 g/100 mL) was found to be the most effective under higher manganese condition. Correlation analysis further revealed that economic yield had positive associations with panicle weight, number of panicles per plant, seeds per panicle, test weight, percentage of high-density grains, economic yield, biological yield, and grain harvest index but negatively correlated with sterility percentage.

Conclusion: Among the treatments, bay leaf extract was the best and among the varieties, Dehangi consistently outperformed the other rice varieties under study ahhering the better physiological, biochemical, and yield traits.

KEYWORDS

• Bay kleaf • Banana peel • Iron • Manganese • Potato peel • Rice

INTRODUCTION

Rice is one of the staple food crops in Assam grown as kharif (70%), Rabi (upland) 23% and Boro (7%) covering 2.54 million hectares. The higher iron content in the acid soil (80% of geographical area i.e. 25 mha) of the region is one of the factors for lower productivity (<3tha^{-1}) of the traditional rice genotypes. Moreover, The Northeast India has been experiencing an increase in temperature and rainy days over the years **(Deka *et al*., 2009)**. Climate variability is one of the major sources of risk for farmers who depend on crop production (De and Bodosa. 2015; Nath and Deka 2010). The high rainfall (>2000 mm) makes the soil acidic in nature (pH<5.0) due to leaching of basic cations (Mandal, 1995; **Asfika et al., 2017;** Mandal *et al*., 2019). So, the ground water contains higher iron (0.25 - 67.0 ppm), where it's adsorption by the plant roots, enriches the concentration of iron in plants. The toxicity of iron is diagnoised as potassium deficiency (at 150-450 ppm), yellowing of green leaves (at 350-450 ppm), dark brown or bronze spots (at 450-780 ppm) and plant lethality at >800 ppm iron in soil (Baruah *et al.,* 1983; Bora and Borkakati, 1997). Although iron toxicity could be lessened by broadcasting potassium fertilizer (Singh and Singh, 1987), managing water (Borah and Nath, 1979), appliying growth hormones, organic acids, coconut milk, and varietal sorting (Bey *et al.,* 2022), applying rice husk and bamboo biochar to soil for adosrption of iron (Laxmanarayanan *et al.,* 2026), little is known about its amelioration by the extracts of bio-inputs viz., bay leaf, banana peel and potato peel... Manganese (Mn) is a vital micronutrient that supports numerous metabolic functions within plant cell organelles. However, when present beyond its threshold level, Mn disrupts normal biochemical activities and becomes toxic, particularly in plants grown on acidic soils (Alejandro *et al*., 2020). Excess Mn accumulation can lead to visual symptoms such as inter veinal or marginal chlorosis and necrotic spotting on leaves (Mora *et al*., 2009). Elevated Mn concentrations also impair photosynthetic efficiency by destabilizing pigments and reducing carbon assimilation (Hauck *et al*., 2003). In the acidic soils of Assam, Mn levels typically range between 3 and 52 ppm, exceeding the critical soil limit of 2-3 ppm. In plants, the corresponding toxicity threshold is around 15-20 ppm on a dry weight basis (Basumatary *et al*., 2014).

Bay leaf contains important nutrients (Batool *et al*., 2020; Cakmak *et al*., 2013) viz., Ca (377mg/100g), P (112mg/100g), K (550mg/100g), Fe (45mg/100g), Cu (0.63mg/100g), Mg (112mg/100g), Mn (7.313mg/100g), and Zn (2.90mg/100g). A medium-sized banana has 450- 467mg of potassium. Banana peel contains dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids, and potassium (Emaga, *et al*., 2007), macro and micronutrients, phenolic compounds, fat, and fiber (Nguyen, *et al*.,2003; Sidhu and Zafar, 2018). The minerals with the highest concentrations in raw potato (Burton, 1989; Buckenhüskes, 2005, Karan, 2023) are potassium (564mg/g f.w.), phosphorus (30-60mg/g f.w.), and calcium (6-18mg/g f.w.). Potatoes also contain primarily determined by yield parameters such as tillers per plant, grains per spike, and grain weight per thousand (Gupta *et al*. 1999; Chowdhury *et al*. 2000).

In the first experiment, results on correlation coefficient **(Table 1)** revealed that panicle length is positively correlated with panicle weight (.726**), panicle number per plant (.756**), no. of seeds per panicle (.834**), test weight (.901**), HD grains (.866**), economic yield (.979**), biological yield (.935**), grain harvest index (.837**) but it's negatively correlated with sterility percent (-.780**). Panicle weight is positively correlated with panicle number per plant (.916**), number of seeds per panicle (.820**), test weight (.892**), HD grains (.695**), economic yield (.719**), biological yield (.805**), grain harvest index (.865**) but it is negatively correlated sterility percent (-.746**). Panicle number per plant is positively correlated with number of seeds per panicle (.847**), test weight (.921**), HD grains (.736**), economic yield (.782**), biological yield (.820**), Grain harvest index (.915**) but is negatively correlated with sterility percent (-.819**). Number of seeds per panicle is positively correlated with test weight (.867**), HD grains (.848**), economic yield (.841**), biological yield (.822**), Grain Harvest index (.883**) but negatively correlated with grain sterility percent (-.851**). Test weight is positively correlated with HD grains (.807**), economic yield (.896**), biological yield (.925**), Grain harvest index (.912**), but it is negatively correlated with sterility percent (-.824**). HD grains is negatively correlated with sterility percent (-.758**) but positively correlated with economic yield (.846**), biological yield (.888**) and grain harvest index (.840**). Sterility percent is negatively correlated with economic yield (-.805**), biological yield (-.754**) and grain harvest index (-.819**). Economic yield is positively correlated with biological yield (.893**) and grain harvest index (.834**). Biological yield is positively correlated with grain harvest index (.889**). Among the varieties, the highest response score was observed in the variety Dehangi (23), followed by Lachit (04). Varieties Inglongkiri and Luit scored 0. Among the treatments, treatment with 100 ppm FeSO4 plus aqueous bay leaf (10 g in 10ml) recorded the highest response card (22), followed by the treatment with 100 ppm $FeSO_4$ **(Table 2a)**.

Table 1: Relationship between yield and yield attributing parameters under higher iron conditions

	Panicle length	**Panicle weight**	**Panicle no, per plant**	**No. of seeds per panicle**	**Test weight**	**HD Grains**	**Sterility percent**	**Economic yield**	**Biological yield**	**Grain harvest index**
Panicle length	1									
Panicle weight	.726**	1								
Panicle no. per plant	.756**	.916**	1							
No. of seeds per panicle	.834**	.820**	.847**	1						
Test weight	.901**	.892**	.921**	.867**	1					
HD grains	.866**	.695**	.736**	.848**	.807**	1				
Sterility percent	-.780**	-.746**	-.819**	-.851**	-.824**	-.758**	1			
Economic yield	.979**	.719**	.782**	.841**	.896**	.846**	-.805**	1		
Biological yield	.935**	.805**	.820**	.822**	.925**	.888**	-.754**	.893**	1	
Grain Harvest index	.837**	.865**	.915**	.883**	.912**	.840**	-.819**	.834**	.889**	1

Table 2 (b): Response scores of the treatment at maximum tillering (MT) to Heading (70DAS) and harvest stages of rice crop under higher iron condition

Traits \ Treatments	100 ppm $FeSO_4$	100 ppm $FeSO_4$ plus aqueous Bay leaf (10 g in 100 ml)	100 ppm $FeSO_4$ Plus aqueous Banana peel (10 g in 100 ml)	100 ppm $FeSO_4$ plus aqueous Potato peel (10 g in 100 ml)	Natural soil
SLW at MT		✓			
SLW at heading stage		✓			
Plant Height at harvest		✓			
Shoot Biomass at harvest		✓			
No. of tillers at MT		✓			
No. of effective tillers at MT		✓			
No. of leaves at MT		✓			
Root biomass at harvest		✓			
Total chlorophyll content at MT		✓			
Total chlorophyll content at headingstage		✓			
NR activity at MT		✓			
NR activity at heading stage		✓			
Carbohydrate content at harvest		✓			
Cation leakage at MT	✓				
Cation leakage at heading stage	✓				

In the second experiment, the correlation analysis **(Table 3)** highlights significant interrelationships among key yield-related traits. Panicle length showed strong positive correlations with panicle weight (r = .715****), panicle number per plant (r = 0. .745**), number of seeds per panicle (r = 0. 823**), test weight (r = 0. 901**), HD grains (r = 0. 855**), economic yield (r = 0. 968**), biological yield (r = 0. 924**), and grain harvest index (r = 0. 826**), while displaying a significant negative correlation with sterility percentage (r = -0. 770**). Similarly, panicle weight was positively correlated with panicle number per plant (r = 0.906**), number of seeds per panicle (r = 0. 810**), test weight (r = 0. 881**), HD grains (r = 0.685**), economic yield (r = 0.708**), biological yield (r = 0.804**), and grain harvest index (r = 0. 854**), but negatively correlated with sterility percentage (r = -0.736**). Panicle number per plant exhibited strong positive correlations with number of seeds per panicle (r = 0. 836**), test weight (r = 0.910**), HD grains (r = 0.725**), economic yield (r = 0.771**), biological yield (r = 0.810**), and grain harvest index (r = 0.904**), while also negatively correlating with sterility percentage (r = -0.808**). The number of seeds per panicle showed significant positive correlations with test weight (r = 0.856**), HD grains (r = 0.847**), economic yield (r = 0.914**), biological yield (r = 0.811**), and grain harvest index (r = 0.872**), and a negative correlation with sterility percentage (r = -0. 841**). Test weight demonstrated strong positive associations with HD grains (r = 0.806**), economic yield (r = 0.885**), biological yield (r = 0.914**), and grain harvest index (r = 0.901**), and a significant negative relationship with sterility percentage (r = -0.813**). HD grains were positively correlated with economic yield (r = 0.835**), biological yield (r = 0.877**), and grain harvest index (r = 0.830**), while negatively correlated with sterility percentage (r = -0.747**).

Stages	Maximum tillering to heading and harvest stages			
NR activity at heading stage		✓		
Manganese Content at harvest			✓	
Carbohydrate Content at harvest		✓		
Cation Leakage at MT			✓	
Cation Leakage at Heading stage			✓	
Lipid peroxidation at MT			✓	
Lipid peroxidation at heading stage			✓	
Panicle length		✓		
Panicle weight		✓		
Panicle number per plant		✓		
No. of seeds per panicle		✓		
Test weight		✓		
HD grains		✓		
Sterility Percent		✓		
Economic Yield		✓		
Biological Yield		✓		
Grain Harvest Index		✓		
Total response score of the varieties at maximum tillering to Heading stages (70DAS) and harvest stage	00	23	05	00

Based on morphological, physiological, biochemical, and yield-attributing traits, Dehangi consistently showed manganese tolerance, the strongest overall performance with a top response score of 23, regardless of the treatment used. Interestingly, across all varieties, the combination of 200 ppm $MnSO_4$ and an aqueous Bay leaf extract (10 g in 100 ml water) yielded the next highest response score of 22 **(Table 4b)**. According to the findings, bay leaf played a significant role in promoting root growth, noticeably boosting root biomass, which in turn improved nutrient uptake and the production of carbohydrates. This led to improvements across nearly all of the physiological traits.

Table 4(b): Response scores of the treatment at maximum tillering (MT) to Heading (70 DAS) and harvest stages of rice crop

Treatments / Variety	200ppm $MnSO_4$ (control)	200 ppm $MnSO_4$ + aqueous Bay leaf (10 g in 100 ml)	200ppm $MnSO_4$ + aqueous Banana peel (10 g in 100 ml)	200 ppm $MnSO_4$ + aqueous Potato peel (10 g in 100 ml)	Natural soil
SLW at MT		✓			
SLW at heading stage		✓			
Plant Height at harvest		✓			
Shoot Biomass at harvest		✓			
No. of tillers at MT		✓			
No. of effective tillers at MT		✓			
No. of leaves at MT		✓			

table cont....

study period. Physiological indicators such as SLW, plant height, shoot and root biomass, number of tillers and effective tillers, and leaf count per plant improved significantly, particularly in response to bay leaf extract treatment. The enhanced SLW and greater plant height point to improved photosynthetic efficiency and structural development, while increased shoot biomass and tiller numbers reflect robust vegetative growth. Additionally, the substantial increase in root biomass in bay leaf-treated plants suggests improved nutrient acquisition and greater adaptability to stress, contributing to overall plant vigor and productivity.

Test weight, panicle length, panicle weight, and seed count per panicle were all significantly enhanced by bay leaf extract. The extract's ability to improve grain quality and setting is supported by the rise in high-density grains and decrease in sterility percentage. Economic and biological yields also improved dramatically, commensurate with higher grain harvest index values. The findings demonstrate how effectively bay leaf extract supports stress resistance mechanisms, glucose translocation, and grain filling.

CONCLUSION

The study highlights the importance of bay leaf extract as a potential bio-stimulant capable of enhancing rice growth, yield performance, and tolerance to iron toxicity. The observed positive associations between the parameters are largely attributed to its rich composition of phenolic compounds, flavonoids, and potassium. Because, bay leaf greatly increased root biomass and multiplication, which improved nutrient absorption. Finally, these findings contribute to the development of eco-friendly, economically viable strategies for improving rice cultivation in regions affected by iron and manganese stress.

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