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***Dhaincha*-based INM effect on photosynthetic capacity for dry direct-seeded *kharif* rice under different method of sowing**

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Abstract

A field experiment was conducted during the *Kharif* seasons of 2022 and 2023 to evaluate the effect of *Dhaincha*-based integrated nutrient management (INM) on leaf area, leaf number, and Leaf Colour Chart (LCC) value of dry direct-seeded *Kharif* rice (DDSR). The experiment consisted of ten treatments comprising broadcast sowing, line sowing and pellet seeding under 100% recommended dose of fertilizers (RDF) and 75% RDF integrated with *Dhaincha* brown manuring (simultaneous and staggered) and surface application of *Dhaincha* mulch. Salient findings of the experiment revealed that *Dhaincha* based brown manuring in dry direct seeded *kharif* rice can potentially save 25% of recommended chemical fertilizers in terms of photosynthetic capacity such as leaf number, leaf area index and leaf greenness (LCC value). Mulching of green biomass of *Dhaincha* could also be a potential alternative option to improve fertilizer nutrient economy in direct seeded rice. *Dhaincha* brown manuring by its staggered sowing was found to be superior to its simultaneous sowing during first year only. Broadcast sowing was found superior to the average effect of line sowing and pellet sowing in terms of leaf area index, however, the later was superior in terms of greenness of leaves (LCC value). Simple correlation studies showed positive relation of grain yield with leaf number per shoot, leaf area index in both the years and with LCC value in second year only. Hence, the photosynthetic capacity of dry direct seeded rice in terms of leaf number, leaf area and leaf greenness can be improved through the practice of *Dhaincha* mulching irrespective of sowing methods while improving economy of fertilizer nutrient use.

Keywords: Crop establishment, improved IKS, *Sesbania* brown manuring

1. Introduction

Rice (*Oryza sativa* L.) is one of the world's most important cereal crops, and its productivity is critically dependent on morphological and physiological traits. Achieving higher productivity in rice largely depends on improving canopy photosynthesis, which is fundamentally controlled by leaf morphological and physiological traits. Among these, leaf number, leaf area, and leaf greenness play a central role in determining the photosynthetic efficiency and biomass production of the crop (Evans, 1993; Sinclair & Sheehy, 1999) ^[8, 25].

In cereals, grain yield is defined to the crop intercept solar radiation and convert it into biomass, which were influenced by the leaves size, number and functional duration of leaves (Monteith, 1977; Mahajan *et al.*, 2015) ^[19, 17]. Whereas, Green leaf area duration and leaf greenness, which reflect chlorophyll concentration of leaves and have been positively correlated with the higher rates of photosynthesis and crop yield in rice and other cereals (Yoshida *et al.*, 1976; Board & Harville, 1992) ^[31, 5].

Leaf number in rice is closely related to tiller production, which determines effective panicles per unit area, and is influenced by plant population, nutrient availability and management practices (McDonald & Llewellyn, 1993) ^[18]. Each tiller contributes additional leaves, increasing the total photosynthetic surface area per unit land area. However, the relationship is dynamic, excessive plant density may lead to competition for light and nutrients, affecting leaf expansion and chlorophyll synthesis (Lafarge & Hammer, 2002) ^[16].

Leaf area and leaf number together determine the leaf area index (LAI), which controls light interception and canopy structure. A well-developed canopy with optimum leaf area allows

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efficient radiation absorption while minimising mutual shading (Sinclair & Sheehy, 1999) [25]. Sustained green leaf area during reproductive stages ensures continued supply of carbohydrate for grains development, thereby enhancing grain filling and economic yield (Yoshida *et al.*, 1976; Bocianowski *et al.*, 2017) [31, 6].

At the same time, leaf greenness, often measured using leaf colour charts (LCC) or chlorophyll meters, reflects chlorophyll concentration and nitrogen status of the plant. Since nitrogen is a major component of chlorophyll and photosynthetic enzymes, more the greener leaves higher will be photosynthetic rates (Kumar *et al.*, 2011) [14] and greater assimilate production (Fageria *et al.*, 2007) [9].

INM, particularly nitrogen fertilizer, significantly improves leaf numbers, leaf expansion and greenness of rice leaves. Conventionally higher input systems often depend on heavy chemical fertilizers to maximise vegetative growth. However, concerns about soil degradation, nutrient imbalance, and environmental sustainability have led to increased interest in INM, approaches that combine organic and inorganic nutrient sources (Gruhn *et al.*, 2000; Abhale *et al.*, 2024) [11, 1]. Among organic amendments, *Dhaincha* (*Sesbania* spp.) has been recognised as a valuable green manure crop and soil amendment in rice systems due to its rapid biomass production and ability to fix atmospheric nitrogen (Pathak *et al.*, 2003; Balasubramanian *et al.*, 2011; Singh *et al.*, 2019) [20, 2, 27]. *Dhaincha* green manuring has been widely recognised in indigenous knowledge systems (IKS) in many rice-growing regions. Studies shown that *Dhaincha* green manure can compensate for up to 25% of the recommended nitrogen fertilizer, thereby reducing dependence on chemical fertilizer without compromising yield (Bhattacharyya *et al.*, 2008) [4]. The incorporation of *Dhaincha* in integrated nutrient management may positively influence leaf morphological traits by improving soil nitrogen availability and enhancing nutrient synchronisation. Enhanced photosynthetic capacity ultimately translates into improved biomass accumulation and grain yield (Slafer *et al.*, 2014; Zhao *et al.*, 2014) [30, 32].

However, systematic evaluation of how *Dhaincha* based integrated nutrient management influences leaf number, leaf area, and leaf greenness with photosynthetic performance under dry direct-seeded Kharif rice conditions remains limited. Thus, this study aims to assess the effects of *Dhaincha* manuring with reduced fertilizer application on leaf number, leaf area, and leaf greenness of dry direct-seeded rice cultivation.

2. Materials and Methods

The field experiment was conducted during the Kharif seasons of 2022 and 2023 at the Agriculture Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal. The soil of the experimental site was red and lateritic in nature, sandy loam in texture, acidic in reaction and low to medium in available nutrients. The experiment was laid out in a randomized block design with three replications. Ten treatments comprising different crop establishment methods (broadcast sowing, line sowing and pellet seeding) under 100% RDF and 75% RDF integrated with *Dhaincha* brown manuring (simultaneous and staggered sowing) and surface seeding of rice with *Dhaincha* biomass mulching were evaluated. The recommended dose of fertilizer was 80-40-40 kg N-P₂O₅-K₂O ha⁻¹. Parameters such as plant green leaf number per shoot, leaf area index per meter square and leaf greenness analysis by LCC from random third leaf of random five plant were recorded at different growth stages. The correlation of leaf numbers, leaf area index and LCC value of rice with rice yield was examined using the Pearson's correlation coefficient (r). Additionally, nine number of single degrees of freedom contrasts were set to compare the means of relevant treatments or group of treatments

3. Results

3.1 Leaf number per shoot

Leaf number is an important indicator of vegetative growth and crop vigour in rice, as it directly influences canopy development and photosynthetic capacity. In the experiment, *Dhaincha* based INM and different sowing methods significantly influenced number of leaves per shoot of dry direct seeded rice at 90 DAS during both the years of the experimentation (Table 1). INM with staggered sown *Dhaincha* recorded green leaves per p at par with 100% RDF irrespective with the methods of sowing during both the years except pellet seeding (T₉) in first year of experimentation. INM with *Dhaincha* mulching (T₁₀) showed at par result on green leaf production at 90 DAS during both the years of experimentation, was attributed to improved nutrient availability resulted from the decomposition of *Dhaincha* biomass along with the partial application of inorganic fertilizers which improves nutrient mineralization and enhances soil organic matter, thereby promoting vegetative growth and leaf development in rice (Becker *et al.*, 1995; Ghosh *et al.*, 2007; Singh *et al.*, 2013; Pramanik *et al.*, 2014) [3, 10, 26, 23].

Table 1: Some photosynthetic attributes of dry direct seeded rice under *Dhaincha*-based INM and different methods of sowing at grain filling stage (90 DAS)

Treatments	Leaf number shoot ⁻¹		Leaf area index		LCC value	
	2022	2023	2022	2023	2022	2023
T ₁ : BS + 100% RDF	5.2	4.4	2.32	2.51	2.3	1.6
T ₂ : LS + 100% RDF	5.3	4.4	2.68	2.36	3.0	2.5
T ₃ : PS + 100% RDF	5.2	4.7	1.94	2.10	2.9	3.1
T ₄ : BS + DBM _{simul.} + 75% RDF	4.8	3.9	1.66	3.04	3.0	1.5
T ₅ : LS + DBM _{simul.} + 75% RDF	4.3	4.2	1.54	2.19	3.5	2.1
T ₆ : PS + DBM _{simul.} + 75% RDF	4.9	3.9	1.34	2.41	3.5	3.3
T ₇ : BS + DBM _{stagg.} + 75% RDF	5.6	4.2	2.73	2.73	2.4	2.0
T ₈ : LS + DBM _{stagg.} + 75% RDF	5.8	4.6	2.38	2.24	2.7	2.9
T ₉ : PS + DBM _{stagg.} + 75% RDF	5.1	4.6	1.46	2.02	3.5	2.9
T ₁₀ : SB + DM + 75% RDF	5.2	4.6	2.51	2.83	2.1	3.0
SEm (±)	0.2	0.2	0.22	0.17	0.2	0.3
LSD _{0.05}	0.6	0.5	0.66	0.51	0.7	0.8

RDF: Recommended dose of fertilizer (80-40-40 kg N-P₂O₅-K₂O/ha); BS: Broadcast sowing; LS: Line sowing; PS: Pellet seeding; DBM: *Dhaincha* brown manuring; DBM_{simul.}: DBM with simultaneous sowing of seeds of rice and *Dhaincha*; DBM_{stagg.}: DBM with sowing of seeds *Dhaincha* 21 days after sowing of rice; SB: Surface broadcast; DM: *Dhaincha* mulching

Group comparison of treatment means by contrast analysis (Table 2) clearly depicted significant differences of means of green leaf number per plant between INM with simultaneous sown *Dhaincha* and staggered sown *Dhaincha* (C3), the later being the superior during both the years. This could be due to better synchronization between nutrient release from *Dhaincha* brown manuring and the crop nutrient demand reported by Singh *et al.*, (2008) [28] and Saha *et al.*, (2010) [24]. INM with *Dhaincha* mulching recorded significantly higher number of leaves per plant at 90 DAS during second year. Under staggered DBM, pellet sown crop produced significantly less number of green leaves per plant in 2022, but the result was at par with line sowing in 2023.

3.2 Leaf area index

Leaf area is a critical determinant of photosynthetic efficiency and

dry matter accumulation in rice crop. The study revealed that, in terms of leaf area index (LAI), the better result was obtained with broadcast method of sowing and INM with staggered sown DBM and INM with *Dhaincha* mulching during both the years of experimentation (Table 1). In 2022, the highest LAI (2.73) at 90 DAS was recorded with BS + DBM_{stagg.} + 75% RDF (T₇) being at par with T₁, T₂, T₈ and T₁₀. However, in 2023 BS + DBM_{simul.} + 75% RDF (T₄) registered the highest LAI value (3.04) which was at par with the treatments T₁, T₇ and T₁₀. These findings associated with broadcast method of sowing with greater plant density and faster canopy cover. Higher plant density can promote early canopy development and increased leaf area index and therefore enhancing light interception (Peng *et al.*, 1998; Chauhan *et al.*, 2011; Kumar *et al.*, 2013) [21, 7, 15].

Table 2: Comparison of means of different groups of treatments as presented in Table 1

Contrasts	Leaf number shoot ⁻¹		Leaf area index		LCC value	
	2022	2023	2022	2023	2022	2023
C1: 100% RDF (T ₁ -T ₃) vs 75% RDF + <i>Dhaincha</i> (T ₄ -T ₁₀)	5.2 vs 5.1 ns	4.5 vs 4.3 ns	2.31 vs 1.95 *	2.32 vs 2.49 ns	2.8 vs 3.0 ns	2.4 vs 2.5 ns
C2: DBM (T ₄ to T ₉) vs DM (T ₁₀)	5.1 vs 5.2 ns	4.2 vs 4.6 *	1.85 vs 2.51 *	2.44 vs 2.83 *	3.1 vs 2.1 **	2.4 vs 3.0 ns
C3: DBM _{simul.} (T ₄ , T ₅ , T ₆) vs DBM _{stagg.} (T ₇ , T ₈ , T ₉)	4.7 vs 5.5 **	4.0 vs 4.5 **	1.51 vs 2.19 **	2.54 vs 2.32 ns	3.3 vs 2.9 *	2.3 vs 2.6 ns
C4: BS (T ₁) vs LS & PS (T ₂ , T ₃) under 100% RDF	5.2 vs 5.2 ns	4.4 vs 4.5 ns	2.32 vs 2.31 ns	2.50 vs 2.22 ns	2.3 vs 3.0 *	1.6 vs 2.8 **
C5: BS (T ₄) vs LS & PS (T ₅ , T ₆) under DBM _{simul.}	4.8 vs 4.6 ns	3.9 vs 4.1 ns	1.66 vs 1.44 ns	3.04 vs 2.29 **	3.0 vs 3.5 ns	1.5 vs 2.7 **
C6: BS (T ₇) vs LS & PS (T ₈ , T ₉) under DBM _{stagg.}	5.6 vs 5.5 ns	4.2 vs 4.6 ns	2.73 vs 1.92 **	2.72 vs 2.12 *	2.4 vs 3.1 *	2.0 vs 2.9 *
C7: LS (T ₂) vs PS (T ₃) under 100% RDF	5.3 vs 5.2 ns	4.4 vs 4.7 ns	2.68 vs 1.94 *	2.35 vs 2.09 ns	3.0 vs 2.9 ns	2.5 vs 3.1 ns
C8: LS (T ₅) vs PS (T ₆) under DBM _{simul.}	4.3 vs 4.9 ns	4.2 vs 3.9 ns	1.54 vs 1.34 ns	2.18 vs 2.40 ns	3.5 vs 3.5 ns	2.1 vs 3.3 **
C9: LS (T ₈) vs PS (T ₉) under DBM _{stagg.}	5.8 vs 5.1 *	4.6 vs 4.6 ns	2.38 vs 1.46 **	2.23 vs 2.01 ns	2.7 vs 3.5 *	2.9 vs 2.9 ns

RDF: Recommended dose of fertilizer (80-40-40 kg N-P₂O₅-K₂O/ha); BS: Broadcast sowing; LS: Line sowing; PS: Pellet seeding; DBM: *Dhaincha* brown manuring; DBM_{simul.}: DBM with simultaneous sowing of seeds of rice and *Dhaincha*; DBM_{stagg.}: DBM with sowing of seeds *Dhaincha* 21 days after sowing of rice; SB: Surface broadcast; DM: *Dhaincha* mulching. * - Significant as p = 0.05, ** - Significant as p = 0.01 and ns = non-significant

Result as depicted by contrast analysis (Table 2) showed that LAI was significantly lower under INM treatments in 2022, but become at par in 2023. INM with *Dhaincha* mulching (T₁₀) was consistently superior DBM (T₄ to T₉) during both the years suggesting that surface retention help in conserve soil moisture and improve soil physical properties which ultimately expand leaf area and canopy development observed by Singh *et al.*, (2004) [29] and Singh *et al.*, (2013) [26]. INM with staggered sown *Dhaincha* registered significantly higher LAI than INM with simultaneous sown *Dhaincha* in first year only. Broadcast method of sowing recorded higher value of LAI under all scenarios, although the effect was not significant all the times. Line sowing was mostly coming out to be better performance when compared with the pellet seeding under non- INM as well under *Dhaincha* based INM.

3.3 Leaf Colour Chart (LCC) Value

Based on the comparison of treatment means (Table 1) and treatment group means (Table 2) the overall effect can be noted as *Dhaincha* based INM showed at par effect with 100% RDF. This shows that 25% less fertilizer can substitute by organic *Dhaincha* based INM for greater chlorophyll content and

improved nitrogen availability in plant tissues (IRRI, 2002; IRRI, 2024; Pradhan & Mondal, 2013) [12, 13, 22]. *Dhaincha* mulching showed superior effect on LCC in second year, but the effect was not significant (C2 in Table 2). INM with simultaneous sown *Dhaincha* was mostly found to record better result particularly during first year. Uniform plant geometry (line sowing and pellet seeding) was superior to broadcast sowing regarding LCC value of rice leaves at 90 DAS. Pellet seeding was found superior to line sowing method while compared between two uniform plant geometry.

3.4 Correlation studies

The photosynthetic parameters of dry direct seeded rice (DDSR) such as green leaf number per shoot, leaf area index (LAI) and leaf colour chart (LCC) values during grain filling stages (90 DAS) were correlated with grain yield per unit area (Fig. 2). It was found that all the simple correlation coefficient tested were statistically non-significant. Although, grain yield was positively correlated with green leaf number per shoot and LAI, but the correlation was positive with LCC value of leaves at 90 DAS during second year of the experimentation.

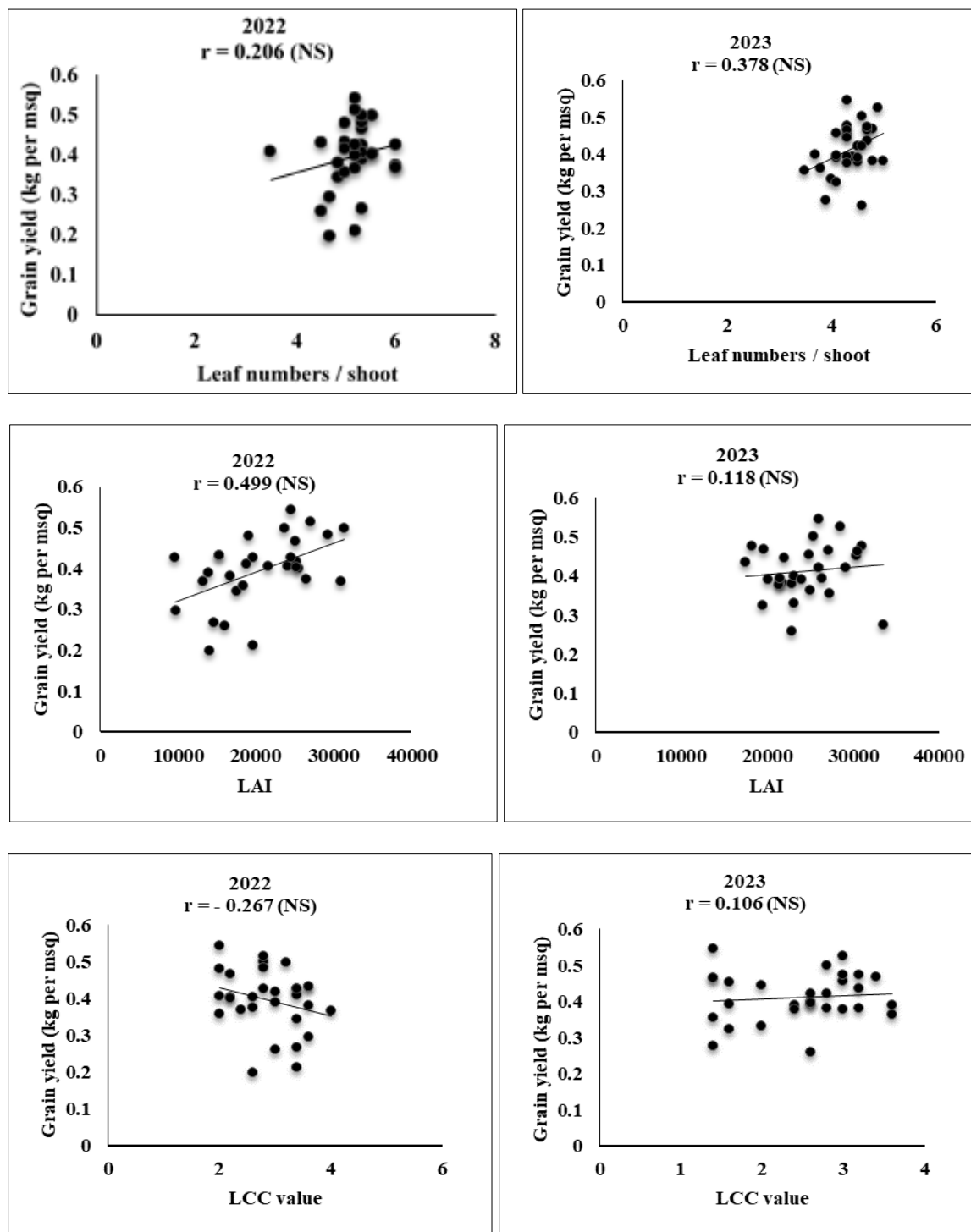


Fig 1: Simple correlation of grain yield of DSR with leaf number, LAI and LCC value at grain filling stage (90DAS)

4. Conclusion

Among the photosynthetic parameters studied in dry direct seeded rice at its grain filling stage (90 DAS), the number of green leaves per shoot and leaf area index (LAI) positively influenced the grain yield. Considering the overall findings of two years of experimentation, it can be concluded that *Dhaincha* based green manuring resulted at par effect with 100% RDF. INM with *Dhaincha* mulching seemed to have a promising effect over *Dhaincha* brown manuring. Staggered sown *Dhaincha* proved to be superior to simultaneous sown *Dhaincha*, while comparing INM with *Dhaincha* brown manuring in first year. Broadcast method of sowing remarkably improved photosynthetic parameters, particularly in terms of LAI over the average effect of the other two methods of sowing (Line sowing and pellet

seeding). Thus, INM based on brown manuring or *Dhaincha* mulching irrespective of method of sowing may be promising in dry direct seeded rice to address better photosynthetic parameters, which, in turn, may lead to realization of better grain yield of the crop under good agricultural practices.

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