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Effect of organic manure, inorganic fertilizer and application of zinc and sulphur micronutrient on the growth and yield components of hybrid Rice (*Oryza sativa* L.) in mid hill region of Himachal Pradesh

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Abstract
A field experiment entitled "Effect of Organic manure, Inorganic fertilizer and application of zinc and sulphur micronutrient on the growth and yield components of hybrid Rice (*Oryza sativa* L.) in mid hill region of Himachal Pradesh" was carried out during the *kharif* of 2024 at the Research Farm, School of Agriculture, Abhilashi University, Chailchowk, Mandi (H.P). The experiment was performed in randomized block design with seven treatments and replicated thrice. The different treatment combination was T_1 = Control, T2 = 50% RDF + 50% Nitrogen through organic sources, T3 = 75% RDF + 25% Nitrogenthrough organic sources, T4 = 100% RDF + Zinc @ 5kg ha-1, T5 = 100% RDF + Sulphur @ 20kg ha-1, T6 = 100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1, T7 = 125% RDF (N113:P50:K50). The study of data revealed that plant growth parameters such as plant height, number of tillers, and dry matter accumulation were significantly enhanced with the application of 125% RDF (N113:P50:K50) T7. Yield attributes, including effective tillers, panicle length, grain number, filled grains, and test weight, were highest in treatment T7 which was statistically at par with T6 treatments. Correspondingly, grain yield (46.92 q ha^{-1}), straw yield (62.92 q ha^{-1}), and biological yield (109.85 q ha^{-1}) were also maximized in T7, indicating the superiority of high-input integrated nutrient strategies. The study concludes that combining organic and inorganic nutrient sources, particularly with zinc and sulphur, significantly improves rice growth and productivity while supporting soil health, thus promoting sustainable rice cultivation.

Keywords: Rice, organic, zinc, sulphur, inorganic

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple foods for nearly half of the world's population, most of them living in developing countries. Rice occupies about 11% of world's agricultural land and ranks second in terms of cultivated area (Kumar *et al.* 2021) [15]. Rice has commercial and industrial importance also beside grains. Rice straw and rice hulls are used as fodder, mulching, packing and as insulation material etc. (Singh & Singh, 2022) [24]. In India, rice production during 2024 was 119.93 million tons with an area under rice cultivation was approximately 47.83 million hectare. In Himachal Pradesh, rice production was 199.00 thousand tons with an area under rice cultivation was approximately 88.16 thousand hectare. The total world rice production was 515.53 million metric tons with an area of 165.98 million hectares and an average productivity of 4.64 metric tons ha-1 (Anonymous, 2024) [3].

Despite the vast area dedicated to rice production, the overall yield remains low due to several interconnected issues. One of the main causes of low production is an imbalance in fertilizer use, and the continued use of inorganic fertilizers has resulted in a decline in soil fertility (Anisuzzaman *et al.* 2021) [2]. Inorganic fertilizers are used indefinitely, causing a decline in soil chemical, physical, and biological qualities, as well as soil health (Singh, 2018) [26]. Chemical fertilizer's negative effects, combined with rising prices, have sparked a surge in interest in organic fertilizers as a nutritional source (Singh, 2018 and Willy *et al.* 2019) [26, 29]. Even while inorganic fertilizers resulted in increased agricultural yields, the overuse of them was linked to deteriorated soil characteristics and degraded soils, resulting in lower yields in the future

(Kumar *et al*. 2019) [14]. Chemical fertilizers, growth regulators, and pesticides are completely reliant on chemical fertilizers, growth regulators, and pesticides in the Western world to boost crop yield. Chemical fertilizer use has been linked to a number of negative health and environmental consequences (Sharada and Sujathamma, 2018) [22]. Taking these factors into account, a middle ground between organic and inorganic fertilizer use for rice cultivation is necessary. Organic farming system is adjudged to be the most viable option to sustain agricultural growth. For maintaining sustainability over long term we have to adopt organic agriculture on the agro-ecosystem (FAO, 2011) [11]. Although using organic manure to maintain and improve soil health has been done for a long time, its practicality is limited because organic sources of nutrients are more expensive and less readily available. In order to maintain soil fertility and generate the highest crop yield with the least amount of inputs, it is necessary to balance fertilization to crops using both inorganic and organic manures, such as farmyard manure, vermicompost, crop residues, and green manuring. Additionally, natural biological pest control and plant protection measures are necessary to support the agro- economic system and soil biological activity (Daphiphaleet *et al*. 2003) [9]. It is widely accepted that neither use of chemical fertilizers alone nor organic manures can achieve the sustainable crop yield under modern intensive farming. A key factor in maintaining rice output and productivity is integrated nutrient management (INM), which increases the effectiveness of applied nutrients. In order to preserve crop production sustainability and meet the growing need for rice grain production, an integration of organic and inorganic fertilizers must be used (Datta and Singh, 2010) [10]. By controlling the fertilizer delivery and reducing nutrient losses to the environment, INM has been demonstrated to significantly increase rice yields and achieve high nutrient use efficiency (Parkinson *et al*. 2013) [18]. When inorganic fertilizers were combined with organic resources, the highest yields of grain and straw were obtained (Arif *et al*. 2014) [4]. Combining chemical fertilizers with organic manure has great potential for enhancing soil fertility and boosting output stability (Bilkis *et al*. 2018) [6].

Zinc is one of the most essential elements for plant growth, especially for rice cultivated in submerged settings. Aside from main minerals, zinc responds quite well to high-intensity cropping systems based on cereals. The P: Zn ratio in plant tissue also facilitates zinc translocation, especially during the seed development period (Muthukumararaja & Sriramachandrasekharan, 2012) [17]. According to (Hemesh, 2020)12v, sulphur is a secondary macronutrient that affects plant growth in two ways: first, by functioning as a nutrient, and second, by influencing the soil conditions. Sulphur is present in methionine, cysteine, and other amino acids that are protein building blocks (Chandel *et al*. 2003) [7].

Methods and Materials

The field investigation was conducted at Research Farm, School of Agriculture, Abhilashi University, Chailchowk, Mandi (H.P.) India, during the *kharif* of 2024. The experimental farm is situated at 30° 32“ N latitude and 74° 53“ E longitude with the elevation of 1391 m above mean sea level. The experimental design consisted of seven treatments laid out in randomized block design (RBD) with three replications. The treatments comprised of T_1 = Control, T2 = 50% RDF + 50% Nitrogen through organic sources, T3 = 75% RDF + 25% Nitrogen through organic sources, T4 = 100% RDF + Zinc @ 5kg ha-1, T5 = 100% RDF + Sulphur @ 20kg ha-1, T6 = 100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1, T7 = 125% RDF (N113:P50:K50). Nutrients were applied as per treatments and recommended doses of N, P, K, Zn and S were applied through Urea, DAP, and MOP, Zinc EDTA and Sulphur. FYM were used as an organic source of manure during investigation. The pH of the experimental soil (before sowing) was slightly acidic in reaction (5.4) with an electrical conductivity of (0.30 dS m-1), low in organic carbon (0.32%), low in available nitrogen (240.76 kg a-1), medium in available phosphorus (16.12 kg ha-1), potassium (260.54 kg ha-1), low in available zinc (0.40 mg kg-1) and medium in available sulphur (14.10 kg ha-1). The spacing for the tested variety hybrid paddy pusa-1121 was 20 × 10 cm, row to row and plant to plant.

Plant sampling

Throughout the investigation, a number of growth parameters were recorded, including plant height, the number of tillers and the dry matter accumulation. Yield parameters, such as effective tillers (m-2), panicle length (cm), number of grains panicle-1, number of filled grains panicle-1 and test weight (g) crop yields, such as grain yield, straw yield, biological yield as well as harvest index, were also recorded to preserve the data regarding the impact of various treatments on these parameters.

Statistical analysis

The two-factor analysis of variance (ANOVA) technique was used to statistically analyse the gathered data, and operational statistics (OPSTAT) software was used to modify the mean differences.

Results and discussion Growth parameters

The results regarding the plant height, number of tillers and dry matter accumulation were shown in Table 1, Table 2 and Table 3 and illustrated in Fig.1, Fig. 2 and Fig. 3. The plant height, number of tillers and dry matter accumulation of rice was significantly influenced by the different nutrient management practices at all growth stages except at 30 days after transplanting (DAT), where the differences were statistically non-significant.

Plant height

At 60, 90, and 120 DAT as well as at harvest, notable variations were observed. Treatment T7 recorded the highest plant height (70.25 cm, 104.67 cm, 112.54 cm, and 122.85 cm), which was significantly higher than all other treatments and comparable to treatment T6 (65.45 cm, 101.31 cm, 108.71 cm, and 116.37 cm). The cumulative effect of a balanced nutrient supply especially nitrogen, zinc, and sulphur, which are essential for vegetative growth is probably what caused the height increase. The fact that the control (T1) stayed at the lowest (94.54 cm) suggests that the plant's growth was impeded by the absence of nutrients. The increase in plant height can be attributed to the higher nutrient availability, particularly nitrogen, which might vital for vegetative growth and cell elongation. The combination of macronutrients (N, P, K and S) with micronutrients (Zn) likely enhanced nutrient uptake efficiency, resulting in vigorous plant growth (Ali *et al*. 2013) [1]. The superiority of confirms the positive impact of increased nutrient dose on crop performance, supporting findings by (Singh *et al*. 2020) [23], who reported enhanced plant height and biomass with higher nutrient inputs.

Table 1: Effect of organic and inorganic nutrient management on plant height (cm) of various stages of transplanted rice

Sr. No.	Treatment	Plant height (cm)				
		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T1	Control	12.02	46.04	71.83	82.95	88.29
T2	50% RDF + 50% Nitrogen through organic sources	14.90	56.06	86.50	95.36	101.70
T3	75% RDF + 25% Nitrogen through organic sources	15.88	57.74	90.03	97.83	105.83
T4	100% RDF + Zinc @ 5kg ha-1	17.98	60.20	92.70	101.35	108.63
T5	100% RDF + Sulphur @ 20kg ha-1	18.73	62.02	95.06	104.26	111.93
T6	100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1	19.81	65.45	101.31	108.71	114.71
T7	125% RDF (N113:P50:K50)	21.26	70.25	104.67	112.54	120.85
S.Em (±)		2.74	2.48	3.70	3.75	3.98
CD (P=0.05)		NS	5.32	7.94	8.05	8.55

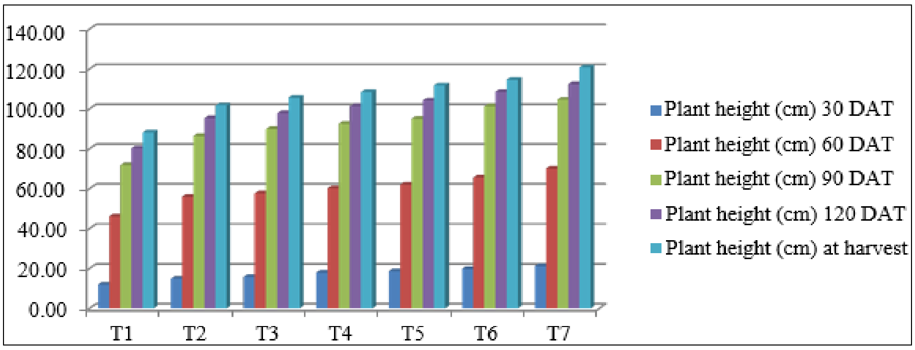

Fig 1: Effect of organic and inorganic nutrient management on plant height (cm) of various stages of transplanted rice

Number of tillers (m-2)

Among the various treatments, treatment T7 recorded the highest number of tillers (246.28, 275.42, 312.53, and 306.78 m-2), which was substantially better than all other treatments and comparable to treatment T6 (235.50, 266.10, 300.33, and 295.82 m-2). During the study, treatment T1 (control) had the fewest tillers (201.59 m-2) which suggests that a shortage of nutrients led to reduced plant growth, which in turn affected the number of tillers.

The increased number of tillers can be attributed due to the higher nutrient availability that supported better vegetative growth and enhanced tillering. This aligns with findings from (Reddy *et al.* 2013) [20] who reported improved tiller production with higher N, P and K application. Combine application of RDF along with micronutrients like zinc and sulphur had proved highly effective due to the synergistic effect of micronutrients in enhancing nitrogen use efficiency and promoting tiller formation (Yadav *et al.* 2015) [32].

Table 2: Effect of organic and inorganic nutrient management on no. of tillers (m-2) at 30, 60, 90, 120 DAT and at harvest of transplanted rice

Sr. No.	Treatment	No. of tillers (m-2)				
		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T1	Control	72.44	139.34	197.26	212.35	207.59
T2	50% RDF + 50% Nitrogen throughorganic sources	82.50	152.24	213.42	223.87	219.07
T3	75% RDF + 25% Nitrogen through organic sources	86.34	169.88	228.92	245.18	240.59
T4	100% RDF + Zinc @ 5kg ha-1	98.15	187.13	236.89	257.44	255.27
T5	100% RDF + Sulphur @ 20kg ha-1	102.22	217.26	243.13	265.21	259.51
T6	100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1	108.78	235.50	266.10	300.33	295.82
T7	125% RDF (N113:P50:K50)	110.65	246.28	275.42	312.53	306.78
S.Em (±)		13.76	11.74	8.56	11.81	11.74
CD (P=0.05)		NS	16.46	18.36	25.34	25.20

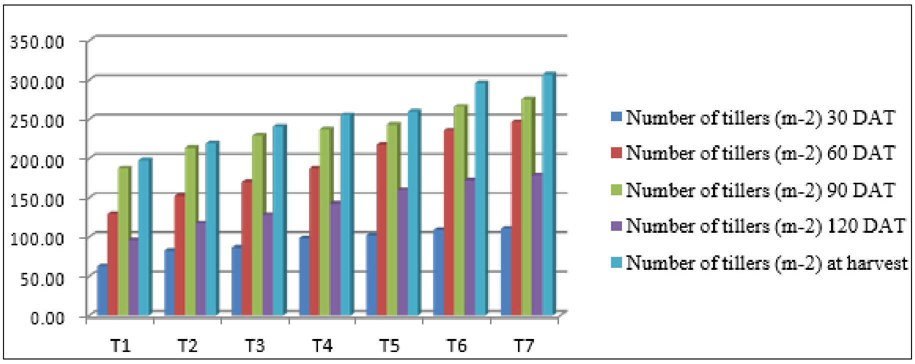

Fig 2: Effect of organic and inorganic nutrient management on no. of tillers (m-2) at 30, 60, 90, 120 DAT and at harvest of transplanted rice

Dry matter accumulation (g m⁻²)

A key measure of crop development and production, dry matter accumulation (g m-2) in rice plants represents the net result of photosynthesis and nutrient assimilation. While differences at 30 DAT were statistically non-significant, dry matter accumulation rose gradually with crop age during the research and was significantly influenced by nitrogen management strategies from 60, 90, and 120 DAT and at harvest onward. In comparison to treatment T6 (504.03, 720.45, 864.73, and 978.07 g m-2), treatment T7 had the largest dry matter accumulation (g m^{-2}) (532.19, 751.71, 902.12, and 1011.79 g m-2). Lower dry matter accumulation was the result of a lack of nutrients, as evidenced by the treatment T1 (control), which stayed at the lowest (335.76 g m-2). The results clearly demonstrate that integrated and enhanced nutrient management practices significantly improve dry matter accumulation in rice. This aligns with findings by (Singh *et al.* 2019) [25], who reported increased biomass production with higher nutrient availability. Combined application of inorganic nutrients with secondary elements like zinc and sulphur also led to significantly improved dry matter accumulation, particularly due to their roles in enzymatic activity, chlorophyll formation, and nitrogen metabolism (Tiwari *et al.* 2020) [28].

Table 3: Effect of organic and inorganic nutrient management on dry matter accumulation (g m-2) at 30, 60, 90, 120 DAT and at harvest of transplanted rice

Sr. No.	Treatment	Dry matter accumulation (g m-2)				
		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T1	Control	94.19	335.76	525.02	690.08	750.75
T2	50% RDF + 50% Nitrogen through organic sources	101.11	354.32	82.76	718.98	827.65
T3	75% RDF + 25% Nitrogen through organic sources	112.31	368.02	606.97	744.41	852.41
T4	100% RDF + Zinc @ 5kg ha-1	125.56	430.58	642.56	783.70	890.70
T5	100% RDF + Sulphur @ 20kg ha-1	132.88	454.47	682.04	824.60	933.94
T6	100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1	140.62	504.03	720.45	864.73	978.07
T7	125% RDF (N113:P50:K50)	142.28	532.19	751.71	902.12	1011.79
S.Em (±)		17.38	16.90	26.72	38.03	33.43
CD (P=0.05)		NS	36.27	57.31	81.59	71.71

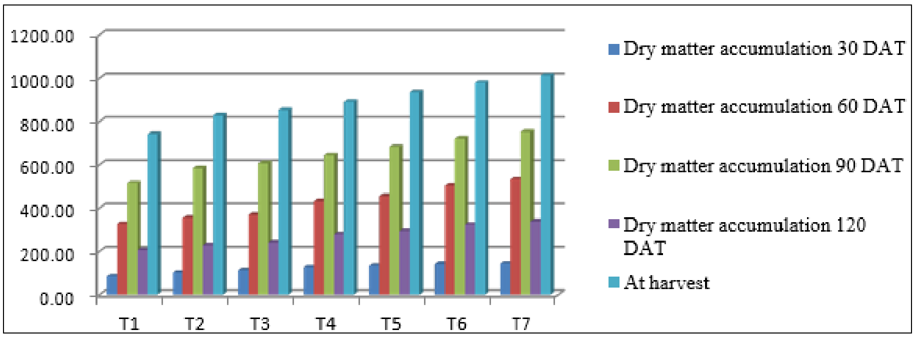

Fig 3: Effect of organic and inorganic nutrient management on dry matter accumulation (g m-2) at 30, 60, 90, 120 DAT and at harvest of transplanted rice

Yield attributes

Table 4 and Fig. 4 give the data on the yield attribute of the rice crop, which includes the number of effective tillers (m-2), panicle length (cm), number of grains (panicle-1), number of filled grains (panicle-1), and test weight (g).

Number of effective tillers (m-2)

The number of effective tillers (m-2) of the rice crop was significantly impacted by the different nutrition management treatments. The number of effective tillers (m-2) of the rice crop was considerably greater in treatment T7 {125% RDF (N113:P50:K50)}, which was statistically equivalent to treatment T6 (100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20 kg ha-1) and better than the other treatments. On the other hand, treatment T1 (control) had the fewest effective tillers (m-2).

Panicle length (cm)

A significant increase in panicle length was observed with the application of nutrients. The highest panicle length (26.80 cm) was recorded in T_7 which was at par with T_6 (25.11 cm). The lowest panicle length (15.11 cm) was found in treatment T1 (control).

Number of grains (panicle-1)

The various treatments had a considerable impact on the number of grains per panicle. Treatment T7 had the most grains per panicle (127 grains/panicle), which was comparable to treatment T6 (121 grains/panicle). Treatment T1 (control) had the fewest grains per panicle.

Number of filled grains (panicle-1)

Similar to grain number, filled grain count was also highest in treatment T_7 (122 grain/panicle) which was at par with treatment T_6 (117 grain/panicle), while the lowest was recorded in treatment T1 (54 grain/panicle).

Test weight (g)

The effect of various treatments was also failed to create significant effects on test weight of rice crop. However, the maximum test weight was recorded in treatment T_7 (28.80g) which was at par with treatment T_6 (26.58 g), while the control (T_1) recorded the lowest (17.78 g).

The findings consistently demonstrate the crucial role of nutrient availability in enhancing rice plant development and yield. Specifically, adequate macro and micronutrient supply, including sulphur and zinc, positively correlates with improved tillering ability, as reported by (Patra *et al.* 2016) [19]. This nutrient optimization also plays a critical role in panicle development, a finding corroborated by (Sarkar and Malik 2019) [21]. The increased grain number observed can be attributed to better nutrient use efficiency and improved reproductive development, aligning with (Kumar *et al.* 2018) [13] findings. Furthermore, enhanced grain filling treatments likely stems from higher photosynthetic availability and efficient nutrient translocation during grain development, a mechanism supported by (Yadav *et al.* 2020) [30]. Finally, the higher test weights in nutrient-rich treatments suggest improved seed development and density, which is consistent with (Mandal *et al.* 2017) [16] emphasis on the importance of sulphur and zinc for seed quality.

Table 4: Effect of organic and inorganic nutrient management on yield attributes of various stages of transplanted rice

Sr. No.	Treatment	Effective tillers (m-2)	Panicle length (cm)	No. of grains (panicle-1)	No. of filled grains (panicle-1)	Test weight (g)
T1	Control	197.26	15.11	62	54	17.78
T2	50% RDF + 50% Nitrogen through organic sources	266.10	18.06	77	68	19.06
T3	75% RDF + 25% Nitrogen through organic sources	285.42	19.23	82	79	20.56
T4	100% RDF + Zinc @ 5kg ha-1	305.82	21.56	94	86	21.90
T5	100% RDF + Sulphur @ 20kg ha-1	335.76	23.89	107	101	24.55
T6	100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1	368.02	25.11	121	117	26.58
T7	125% RDF (N113:P50:K50)	384.69	26.80	127	122	28.80
S.Em (±)		12.95	0.92	3.43	3.51	3.28
CD (P=0.05)		27.78	1.99	7.36	7.53	NS

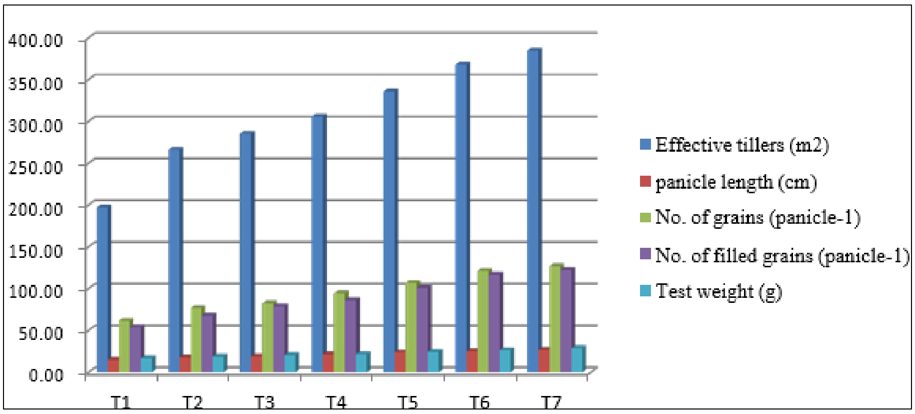

Fig 4: Effect of organic and inorganic nutrient management on yield attributes of various stages of transplanted rice

Yields

The data regarding the yields of rice crop *i.e.*, Grain yield (q ha-1), Straw yield (q ha-1) and Biological yield (q ha-1) is presented in Table 5 and illustrate in Fig. 5.

Grain yield (q ha-1)

Grain yield was significantly influenced by the treatments. The highest grain yield (46.92 q ha^{-1}) was recorded under treatment T_7 {125% RDF: (N_{113}:P_{50}:K_{50})} which was at par with treatment T_6 (44.81 q ha^{-1}). The lowest grain yield (28.35 q ha^{-1}) was observed in treatment T_1 (control). The improvement in grain yield under T_7 and T_6 can be attributed to improved nutrient availability and uptake, leading to enhanced photosynthetic efficiency and better translocation of assimilates to the grains. These findings are in agreement with (Mandal *et al.* 2017 and Kumar *et al.* 2018) [16, 13], who reported that both RDF and micronutrient supplementation positively affect rice grain yield. Application of micronutrients such as zinc and sulphur also significantly increased yield over RDF alone, with the combined application of both Zn and S further enhancing grain yield. Zinc plays a crucial role in enzymatic activity and auxin production, while sulphur is essential for protein synthesis and chlorophyll formation (Tiwari and Nayak, 2018) [27]. Their combined application likely improved nutrient uptake efficiency and overall crop vigor.

Straw yield (q ha-1)

Straw yield followed a similar trend as grain yield. The maximum straw yield was recorded in treatment T_7 (62.92 q ha^{-1}) which was at par with treatment T_6 (59.34 q ha^{-1}), while the treatment T1 (control) registered the lowest value (38.69 q ha^{-1}). Enhanced vegetative growth under nutrient-rich treatments contributed to increased straw biomass. Similar results were reported by (Yadav *et al.* 2020) [31], who found that the application of zinc and sulphur with RDF significantly increased straw production in rice. Straw yield showed a consistent increase across treatments in the control to higher. The higher vegetative biomass in nutrient-rich treatments reflects better photosynthetic activity and plant growth. Integrated nutrient management treatments also performed well in terms of straw yield supporting the notion that balanced nutrition improves overall plant biomass (Yadav *et al.* 2020) [30]

Biological yield (q ha-1)

Biological yield, a cumulative measure of grain and straw yield, was highest in T_7 (109.85 q ha^{-1}) which was at par with treatment T_6 (104.15 q ha^{-1}). The treatment T_1 (control) yielded the lowest biological output (60.71 q ha^{-1}). Higher biological yields in T_6 and T_7 treatments reflect the synergistic effect of primary, secondary, and micronutrient application. This result aligns with (Sarkar and Malik 2019) [21], who emphasized the role of integrated nutrient application in improving overall biomass production. Biological yield, which is the sum of grain and straw yields, followed a similar pattern. It indicates that higher nutrient application not only enhanced the grain output but also contributed to better vegetative development. The increase in biological yield under integrated nutrient management is consistent with previous studies that link nutrient balance to higher productivity (Bharati *et al*. 2014) [5].

Harvest index (%)

The harvest index of rice crop is presented in Table 4.5 and illustrate in Fig. 4.5. Although the harvest index did not show statistically significant differences among treatments (as indicated by the non-significant CD value), a slight numerical increase was observed in the nutrient-enriched treatments. Treatment (T2) recorded the highest harvest index (43.16%). The lowest harvest index was observed in treatment T1 control (42.28%). A higher harvest index in these treatments may be due to better partitioning of assimilates toward grain production. However, the lack of significant differences suggests that while total productivity increased, the relative distribution between grain and straw remained consistent across treatments, as also noted by (Chaudhary and Sinha 2007) [8].

Table 5: Effect of organic and inorganic nutrient management on grain yield (q ha-1), straw yield (q ha-1), biological yield (q ha-1) and harvest index (%) of transplanted rice crop

Sr. No.	Treatment	Grain yield (q ha-1)	Straw yield (q ha-1)	Biological yield (q ha-1)	Harvest index (%)
T1	Control	28.35	38.69	67.04	42.28
T2	50% RDF + 50% Nitrogen through organic sources	33.09	43.57	76.66	43.16
T3	75% RDF + 25% Nitrogen through organic sources	35.29	47.22	82.51	42.77
T4	100% RDF + Zinc @ 5kg ha-1	38.31	52.10	90.41	42.37
T5	100% RDF + Sulphur @ 20kg ha-1	41.93	55.60	97.53	42.99
T6	100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20kg ha-1	44.81	59.34	104.15	43.02
T7	125% RDF (N113:P50:K50)	46.92	62.92	109.84	42.71
S.Em (±)		1.81	2.23	3.62	5.04
CD (P=0.05)		3.90	4.80	7.76	NS

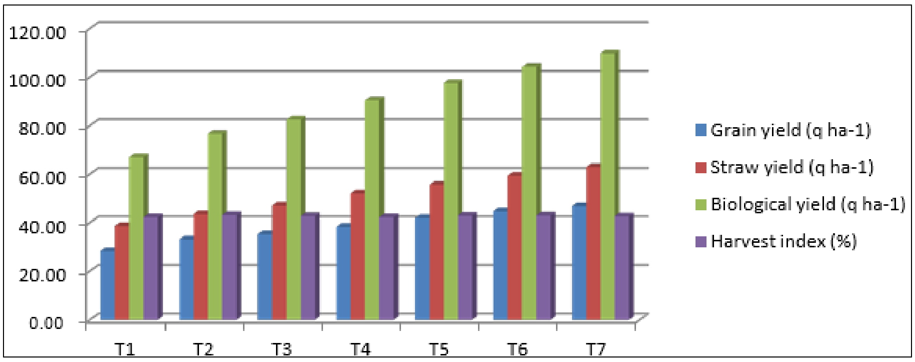

Fig 5: Effect of organic and inorganic nutrient management on grain yield (q ha-1), straw yield (q ha-1), biological yield (q ha-1) and harvest index (%) of transplanted rice crop

Conclusion

The current study unequivocally showed that, in Himachal Pradesh's mid-hill climate, the administration of micronutrients, inorganic fertilizer, and organic manure greatly enhances hybrid rice's growth, yield characteristics, and yield. In terms of plant height, tiller number, dry matter accumulation, and grain production, the treatments T7 {125% RDF (N113:P50:K50)} and T6 (100% RDF + Zinc @ 5 kg ha-1 + Sulphur @ 20 kg ha-1) performed particularly well.

Utilizing macronutrients in conjunction with micronutrients such as sulphur and zinc improved crop vigor, production potential, and nutrient usage efficiency. When combined, organic and inorganic sources increased crop productivity and soil fertility more than when used separately. Thus, maintaining rice yield and long-term soil health requires coordinated and balanced nutrition solutions.

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Conflict of Interest

None of the above author has a conflict

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