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Evaluation of agrotechniques for enhancing grain yield and economic returns of irrigated wheat (*Triticum aestivum* L.) in Chhattisgarh plains

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Abstract

A field experiment was conducted during the *Rabi* seasons of 2021–22 and 2022–23 at Instructional-cum-Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, to evaluate different agrotechniques for enhancing grain yield and profitability of irrigated wheat. The experiment was carried out in Randomized Block Design with twelve treatments and replicated thrice. The experiment comprised and criss-cross sowing + soil test based nutrients + foliar application of 19:19:19 NPK @1%. Results revealed that different sowing methods and nutrient-management practices were evaluated. T₈ (criss-cross sowing + soil test-based nutrients + foliar application of 19:19:19 NPK @ 1%) recorded the highest mean grain yield of 47.55 q ha⁻¹, which was significantly at par with T₁₀ (46.30 q ha⁻¹) and T₁₁ (46.09 q ha⁻¹). Treatment T₈ also recorded the highest mean gross return (Rs. ha⁻¹ 1,36,244) and net return (Rs. ha⁻¹ 1,05,368), followed by T₁₀ and T₁₁. The lowest grain yield (30.58 q ha⁻¹), gross return (Rs. ha⁻¹ 92788) and net return (Rs. ha⁻¹ 65511) were recorded under T₁₂. The study indicated that criss-cross sowing integrated with soil test-based nutrient management and foliar application of 19:19:19 NPK was effective in enhancing grain productivity and profitability of irrigated wheat under the Chhattisgarh Plains.

Keywords: Wheat, criss-cross sowing, grain yield, soil test-based nutrient, foliar application, gross return, net return, profitability

Introduction

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops of the world and plays a major role in global food and nutritional security. Bread wheat is the predominant cultivated species in India owing to its high yield potential, wide adaptability and good grain quality. Globally, wheat is cultivated on about 221 million hectares, producing 789.6 million tonnes with an average productivity of 3779 kg ha⁻¹ (FAO, 2024) [3]. Delayed sowing is a major constraint to wheat productivity, particularly in rice–wheat cropping systems, due to late harvesting of preceding rice, inadequate field preparation and unfavourable weather conditions. Under such situations, efficient crop establishment and resource utilization through improved sowing methods are essential. Criss-cross sowing can improve plant distribution and productive tillers per unit area, while furrow-irrigated raised-bed (FIRB) planting can enhance water-use efficiency and crop productivity. FIRB systems have been reported to save about 20–50 per cent irrigation water in wheat (Hobbs and Gupta, 2003) [6]. Nutrient management is equally important for achieving higher wheat productivity. Foliar application of balanced water-soluble NPK (19:19:19) can provide nutrients rapidly during critical growth stages and support photosynthetic activity, tiller development and grain filling. Thus, integration of improved sowing geometry with efficient nutrient management may enhance productivity and profitability of wheat, particularly under irrigated conditions. Soil test-based nutrient management involves the application of fertilizers according to soil nutrient status and crop demand, which ensures balanced and efficient nutrient supply to wheat crop. This approach improves nutrient use efficiency, enhances crop growth, yield attributes, and grain productivity.

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Material and Methods

The experiment was conducted during *Rabi* season of 2021- 22 and 2022-23 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). Climate of the region is sub-humid with hot summer and cold winter with an average annual rainfall 1267 mm. The soil of experimental field was clayey (*Vertisols*), neutral in reaction (pH 7.1), medium in organic carbon (0.61%) and low in available nitrogen (222.7 kg ha⁻¹), medium in available phosphorus (13.8 kg ha⁻¹) and high in available potassium (373.2 kg ha⁻¹). The experiment was carried out in randomized block design with twelve treatments, replicated thrice. Treatment comprised herbicides viz., Flat bed normal sowing + STB nutrients (NPK), Flat bed with Crisscross sowing + STB nutrients, Raised bed sowing + STB nutrients, Flat bed with Crisscross sowing + STB nutrients + seed treatment with PSB & Azotobacter, Raised bed sowing + STB nutrients + seed treatment with PSB and Azotobacter, Flat bed with Crisscross sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, Raised bed sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, Flat bed with Crisscross sowing + STB nutrients + foliar spray of 19:19:19 NPK @ 1%, Raised bed sowing + STB nutrient + foliar spray of 19:19:19 NPK @ 1%, Flat bed with Crisscross sowing + 150% of STB nutrients, Flat bed with Crisscross sowing + 150% of STB nutrients + Growth retardant (Cycocel 0.2%), Flat bed normal sowing + RDF (120:60:40 Kg NPK ha⁻¹) (Standard Check). Sowing was done manually using 120 kg ha⁻¹ seeds of CG-1029 cultivar in rows of 20 cm in line sowing, 20 × 20 cm row in criss-cross. NPK applied through the soil test based in the form of urea, single superphosphate (SSP) and muriate of potash (MOP), respectively as basal dose of SSP and MOP but 2 split dose of urea. Influence of above mentioned treatments on wheat was studied for seed yields and economics of wheat. Yield of wheat and economics were computed and analyzed statistically using F- test, the procedure given by Gomez and Gomez (1984) [4]. Critical difference (CD) values at P=0.05 were used to determine the significance of mean differences of treatments.

Gross return (kg ha⁻¹)

The gross return in rupees per hectare was calculated separately for each treatment by converting seed yield and seed rate on the basis of prevailing prices of market.

Net return (kg ha⁻¹)

- Net return of crop was obtained by deducting cost of cultivation from gross return.
- Net return (₹ ha⁻¹) = Gross return (₹ ha⁻¹) – Cost of cultivation (₹ ha⁻¹)

B: C ratio

The B: C ratio was worked out by using the following formula (as described by Reddy & Reddy) [11].

$$\text{B:C Ratio} = \frac{\text{Gross Return (Rs. ha}^{-1}\text{)}}{\text{Cost of Cultivation (Rs. ha}^{-1}\text{)}}$$

Result and Discussion

Significantly the highest grain yield (4636 kg ha⁻¹ and 4874 kg ha⁻¹) was recorded under T₈ – Criss cross sowing + STB nutrients + foliar spray of 19:19:19 NPK which was statistically at par with T₁₀ – Criss cross sowing + 150% STB nutrients (4548 kg ha⁻¹ and

4711 kg ha⁻¹), T₁₁ – Criss cross sowing + 150% STB nutrients + growth retardant CCC (4516 kg ha⁻¹ and 4702 kg ha⁻¹) and T₆ – Criss cross sowing + STB nutrients + Bio-enriched Vermicompost (4198 kg ha⁻¹ and 4339 kg ha⁻¹) during 2021–22 and 2022–23. The lowest grain yield (2953 kg ha⁻¹ and 3163 kg ha⁻¹) was recorded under T₁₂ – Line sowing + RDF considered as the standard check which was statistically at par with T₁ – Flat normal sowing + STB nutrients and T₃ – Raised bed + STB Nutrients during 2021-22 and 2022-23. In comparison to the standard check (T₁₂ – Line sowing + RDF), the grain yield under T₈ – Criss cross sowing + STB nutrients + foliar spray of 19:19:19 NPK was recorded 56.99 per cent higher during 2021-22 and 54.09 per cent during 2022-23. Similarly, T₁₀ – Criss cross sowing + 150% STB nutrients recorded 54.01 per cent during 2021-22 and 48.96 per cent during 2022-23, T₁₁ – Criss cross sowing + 150% STB nutrients + growth retardant CCC recorded 52.93 per cent higher grain yield during 2021-22 and 48.66 per cent during 2022-23 and T₆ – Criss cross sowing + STB nutrients + Bio-enriched Vermicompost also recorded 42.16 per cent higher grain yield during 2021-22 and 37.18 per cent during 2022-23, respectively, over the standard check (T₁₂). On the basis of mean analysis of two years data, T₈ – Criss cross sowing + STB nutrients + foliar spray of 19:19:19 NPK recorded the highest numerical grain yield which was at par with, T₁₀ – Criss cross sowing + 150% STB nutrients, T₁₁ – Criss cross sowing + 150% STB nutrients + growth retardant CCC and T₆ – Criss cross sowing + STB nutrients + Bio-enriched Vermicompost. Higher yielding Treatment T₈, T₁₀, T₁₁ and T₆ resulted in 56.99, 54.09, 52.93 and 42.16 per cent increase in grain yield over the standard check T₁₂ – Line sowing + RDF, respectively. Higher grain yield under these treatments may be attributed to better crop establishment and spatial distribution under criss cross sowing, along with improved nutrient availability through enhanced nutrient application and foliar nutrition, which might have promoted better yield attributes and efficient partitioning of assimilates towards grain formation. Increased grain yield due to soil test based fertilizer application was also reported by Singh *et al.* (2020) [12] and Kumari *et al.* (2022) [9]. Similarly enhanced grain yield due to foliar nutrition of 19:19:19 was reported by Jat *et al.* (2019) [7], Ninama *et al.* (2023) [10]. Increased grain yield due to application of bio enriched Vermicompost or FYM was also reported by Singh (2019) [13] and Bhargava *et al.* (2025) [1].

On mean basis, the highest cost of cultivation was recorded under T₉ – Raised bed sowing + STB nutrient + foliar spray of 19:19:19 NPK @ 1% (32,228 Rs ha⁻¹), followed by T₇ – Raised bed sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹ (Rs. 31, 208 ha⁻¹), T₁₁ – Flat bed with Crisscross sowing + 150% of STB nutrients + Growth retardant Cycocel 0.2% (Rs. 30,967 ha⁻¹) and T₈ – Criss cross sowing + soil test-based nutrients + foliar spray of 19:19:19 NPK @1%, whereas the lowest mean cost of cultivation was recorded under T₁ – Flat bed + Flat bed normal sowing + STB nutrients, NPK (Rs. 26426 ha⁻¹), followed by T₂ – Flat bed with Crisscross sowing + STB nutrients (Rs. 27,201 ha⁻¹) and T₁₂ – Flat bed normal sowing + RDF 120:60:40 Kg NPK ha⁻¹ as Standard Check (Rs. 27,277 ha⁻¹).

On the basis of mean analysis of two years data, T₈ recorded the highest mean gross return (Rs. 1,36,244 ha⁻¹), which was statistically at par with T₁₀ – Criss cross sowing + 150% soil test-based nutrients (Rs. 1,33,083 ha⁻¹), T₁₁ – Criss cross sowing + 150% soil test-based nutrients + growth retardant CCC (Rs. 1,32,438 ha⁻¹) and T₆ – Criss cross sowing + soil test-based nutrients + bio-enriched vermicompost (Rs. 1,24,505 ha⁻¹). The

lowest mean gross return was recorded under T₁₂ (Rs. 92,788 ha⁻¹), which remained statistically at par with T₁ – Flat sowing + soil test-based nutrients (Rs. 97,243 ha⁻¹) and T₃ – Raised bed + soil test-based nutrients (Rs. 1,05,107 ha⁻¹). Compared with the standard check, T₈, T₁₀ and T₁₁ recorded 46.83, 43.43 and 42.73 per cent higher mean gross return, respectively. On the basis of mean analysis of two years data, T₈ recorded the highest mean net return (Rs. 1,05,368 ha⁻¹), which was statistically at par with T₁₀ – Criss cross sowing + 150% soil test-based nutrients (Rs. 1,03,376 ha⁻¹), T₁₁ – Criss cross sowing + 150% soil test-based nutrients + growth retardant CCC (Rs. 1,01,471 ha⁻¹) and T₆ – Criss cross sowing + soil test-based nutrients + bio-enriched vermicompost (Rs. 94,649 ha⁻¹). The lowest mean net return was recorded under T₁₂ (Rs. 65,511 ha⁻¹), which remained statistically at par with T₁ – Flat sowing + soil test-based nutrients (Rs. 70,817 ha⁻¹) and T₃ – Raised bed + soil test-based nutrients (Rs. 76,554 ha⁻¹). Compared with the standard check, T₈, T₁₀ and T₁₁ recorded 60.84, 57.80 and 54.89 per cent higher mean net return, respectively.

On the basis of mean analysis, T₁₀ recorded the highest benefit: cost ratio (4.47), which was statistically at par with T₈ – Criss cross sowing + soil test-based nutrients + foliar spray of 19:19:19 NPK@ 1% (4.41), T₁₁ – Criss cross sowing + 150% soil test-

based nutrients + growth retardant CCC (4.27) and T₆ – Criss cross sowing + soil test-based nutrients + bio-enriched vermicompost (4.16). The lowest mean benefit: cost ratio was recorded under T₁₂ (3.40), which remained statistically at par with T₁ – Flat sowing + soil test-based nutrients (3.67) and T₃ – Raised bed + soil test-based nutrients (3.67). Compared with the standard check, T₈, T₁₀ and T₁₁ recorded 29.71, 31.47 and 25.59 per cent higher mean benefit: cost ratio, respectively. The superiority of T₈ in terms of gross and net returns demonstrates that integration of improved crop establishment with balanced nutrient management and foliar nutrient supplementation enhanced crop productivity and profitability over the standard cultivation practice. The statistically comparable economic performance of T₁₀, T₁₁ and T₆ further indicated that improved nutrient availability through soil test-based nutrient management, higher nutrient application and organic nutrient supplementation could enhance economic efficiency. The higher benefit: cost ratio under T₁₀ was mainly associated with its high gross return coupled with comparatively lower cost of cultivation than T₈. Similar findings have also been reported by Halford and Singh (2022)^[5], Singh *et al.* (2020)^[12], Jat *et al.* (2019)^[7], Kumar *et al.* (2019)^[8] and Choudhary *et al.* (2013)^[2].

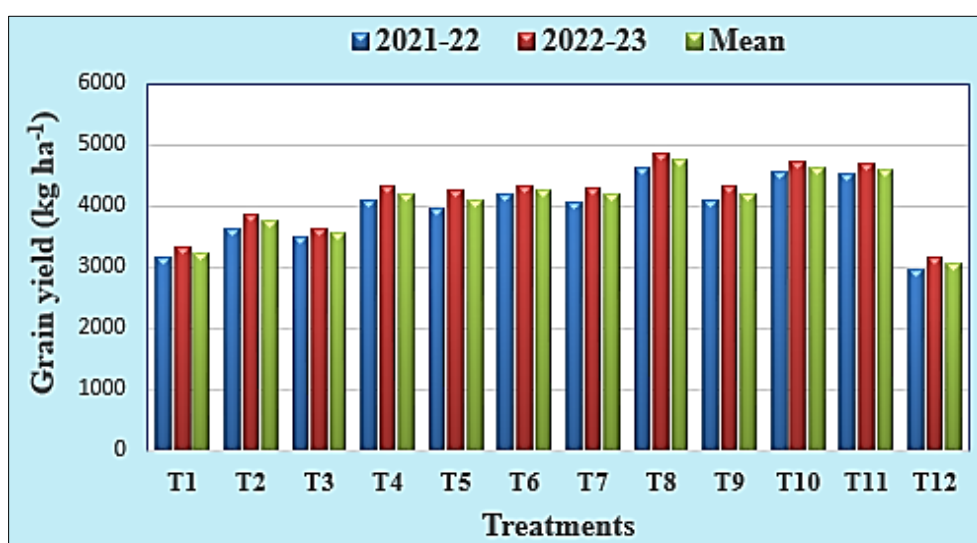


Fig 1: Grain yield (kg ha⁻¹) of wheat crop as influenced by different agrotechniques

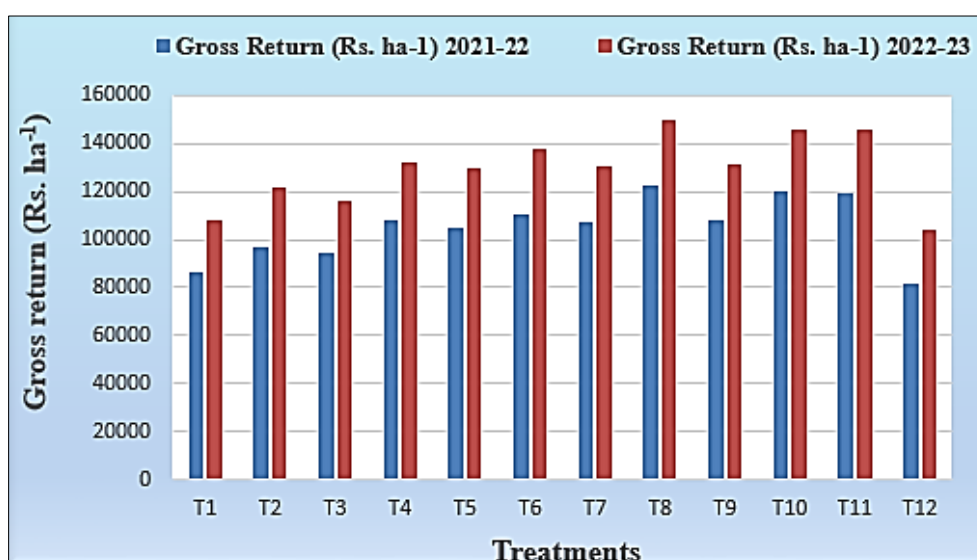


Fig 2: Gross return (Rs. ha⁻¹) of wheat crops influence by different agrotechniques

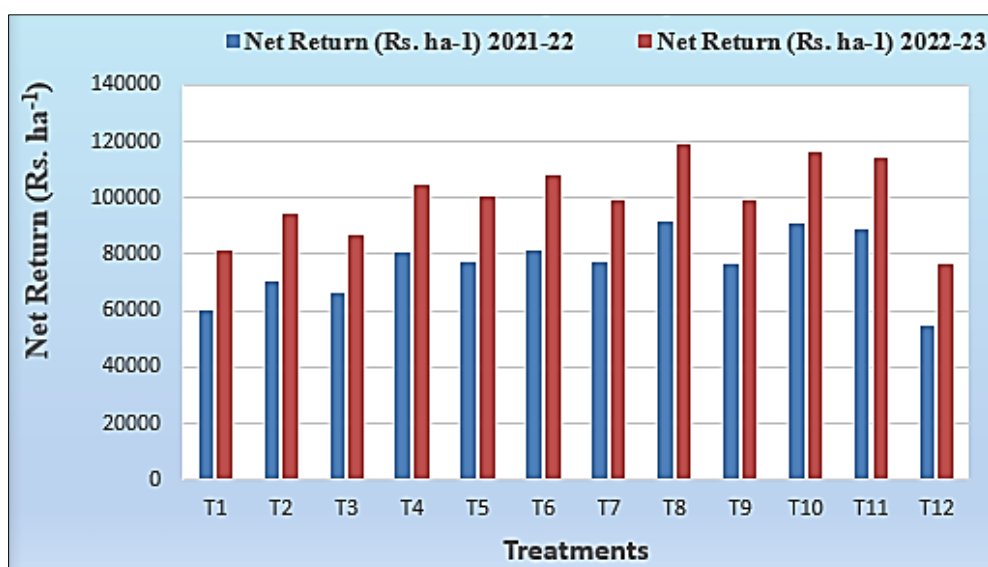


Fig 3: Net return (Rs. ha⁻¹) of wheat crop as influenced by different agrotechniques

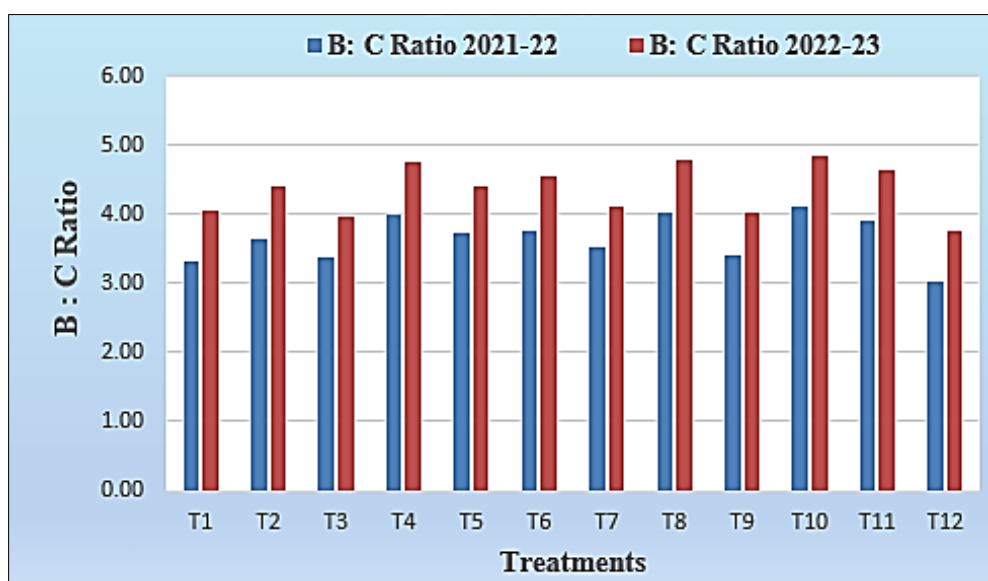


Fig 4: B : C Ratio of wheat crop as influenced by different agrotechniques

Table 1: Grain yield of wheat as influenced by different agrotechniques

Treatments	Grain yield (kg ha ⁻¹)		
	2021-22	2022-23	Mean
T ₁ : Flat bed sowing + STB Nutrients	3144	3337	3240
T ₂ : Criss cross + STB Nutrients	3616	3875	3746
T ₃ : Raised bed + STB Nutrients	3494	3625	3559
T ₄ : Criss cross + STB + PSB & Azoto.	4087	4317	4202
T ₅ : Raised bed + STB + PSB & Azoto.	3968	4248	4108
T ₆ : Criss cross + STB + Bio-enriched VC	4198	4339	4269
T ₇ : Raised bed + STB + Bio-enriched VC	4072	4291	4181
T ₈ : Criss cross + STB + 19:19:19 NPK	4636	4874	4755
T ₉ : Raised bed + STB + 19:19:19 NPK	4081	4311	4196
T ₁₀ : Criss cross + 150% STB Nutrients	4548	4711	4630
T ₁₁ : Criss cross +150% STB + CCC	4516	4702	4609
T ₁₂ : Line sowing+ RDF (Standard check)	2953	3163	3058
SEM±	185	187	156
CD (P=0.05)	544	550	458

*STB- soil test based, Azoto.-Azotobacter, VC-vermicompost, CCC- cycocel

Table 2: Cost of cultivation and gross return of wheat as influenced by different agrotechniques

Treatments	Economics of wheat (Rs. ha ⁻¹)					
	Cost of cultivation (Rs. ha ⁻¹)			Gross return (Rs. ha ⁻¹)		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean
T ₁	26027	26825	26426	86125	108360	97243
T ₂	26777	27625	27201	97219	121769	109494
T ₃	27929	29177	28553	94302	115913	105107
T ₄	27017	27865	27441	107995	132482	120239
T ₅	28169	29417	28793	105160	129801	117480
T ₆	29427	30285	29856	110811	138200	124505
T ₇	30579	31837	31208	107657	130845	119251
T ₈	30429	31322	30876	122247	150240	136244
T ₉	31581	32874	32228	107859	131787	119823
T ₁₀	29283	30131	29707	120009	146157	133083
T ₁₁	30535	31398	30967	119187	145688	132438
T ₁₂	26878	27676	27277	81379	104196	92788
SEm±	-	-	-	4553	5570	4595
CD (P=0.05)	-	-	-	13353	16336	13478

T₁- Flat bed normal sowing + STB nutrients (NPK), T₂ - Flat bed with Crisscross sowing + STB nutrients, T₃ - Raised bed sowing + STB nutrients, T₄ - Flat bed with Crisscross sowing + STB nutrients + seed treatment with PSB & Azotobacter, T₅- Raised bed sowing + STB nutrients + seed treatment with PSB and Azotobacter, T₆- Flat bed with Crisscross sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, T₇- Raised bed sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, T₈- Flat bed with Crisscross sowing + STB nutrients + foliar spray of 19:19:19 NPK @ 1%,

T₉- Raised bed sowing +STB nutrient + foliar spray of 19:19:19 NPK @ 1%, T₁₀- Flat bed with Crisscross sowing + 150% of STB nutrients, T₁₁- Flat bed with Crisscross sowing + 150% of STB nutrients + Growth retardant (Cycocel 0.2%), T₁₂- Flat bed normal sowing + RDF (120:60:40 Kg NPK ha⁻¹) (Standard Check).

Table 3: Net return (Rs. ha⁻¹) and B:C ratio of wheat as influenced by different agrotechniques

Treatments	Economics of wheat (Rs. ha ⁻¹)					
	Net return (Rs. ha ⁻¹)			B: C ratio		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean
T ₁	60098	81535	70817	3.31	4.04	3.67
T ₂	70442	94144	82293	3.63	4.41	4.02
T ₃	66373	86736	76554	3.38	3.97	3.67
T ₄	80978	104617	92798	4.00	4.75	4.38
T ₅	76991	100384	88687	3.73	4.41	4.07
T ₆	81384	107915	94649	3.77	4.56	4.16
T ₇	77078	99008	88043	3.52	4.11	3.82
T ₈	91818	118918	105368	4.02	4.80	4.41
T ₉	76278	98913	87595	3.42	4.01	3.71
T ₁₀	90726	116026	103376	4.10	4.85	4.47
T ₁₁	88652	114290	101471	3.90	4.64	4.27
T ₁₂	54501	76520	65511	3.03	3.76	3.40
SEm±	3623	4437	3670	0.17	0.15	0.15
CD (P=0.05)	10626	13012	10763	0.48	0.44	0.43

T₁- Flat bed normal sowing + STB nutrients (NPK), T₂ - Flat bed with Crisscross sowing + STB nutrients, T₃ - Raised bed sowing + STB nutrients, T₄ - Flat bed with Crisscross sowing + STB nutrients + seed treatment with PSB & Azotobacter, T₅- Raised bed sowing + STB nutrients + seed treatment with PSB and Azotobacter, T₆- Flat bed with Crisscross sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, T₇- Raised bed sowing + STB nutrients + Bio-enriched Vermicompost @ 2.5 q ha⁻¹, T₈- Flat bed with Crisscross sowing + STB nutrients + foliar spray of 19:19:19 NPK @ 1%,

T₉- Raised bed sowing +STB nutrient + foliar spray of 19:19:19 NPK @ 1%, T₁₀- Flat bed with Crisscross sowing + 150% of STB nutrients, T₁₁- Flat bed with Crisscross sowing + 150% of STB nutrients + Growth retardant (Cycocel 0.2%), T₁₂- Flat bed normal sowing + RDF (120:60:40 Kg NPK ha⁻¹) (Standard Check).

Conclusion

Criss cross combination of soil test based nutrients with 19:19:19 NPK foliar spray significantly recorded the highest grain yield (kg ha⁻¹), gross return (Rs. ha⁻¹), net return (Rs.ha⁻¹) and criss cross combined with 150 per cent soil test based nutrients recorded the highest benefit: cost ratio over rest of the treatments. Criss cross combined with soil test based nutrients and 19:19:19 NPK foliar spray proved to be best regarding these parameters.

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