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Effect of different fertility levels and sowing methods on growth, yield and economics of wheat (*Triticum aestivum* L.)

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Abstract
The present experiment titled "Effect of different fertility levels and sowing methods on growth, yield and economics of Wheat (*Triticum aestivum* L.)" was conducted during *rabi* season of 2023-24 at Chamelti Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University, Solan, Himachal Pradesh. Results indicated that among the sowing methods, growth parameters *viz.,* plant height (81.34 cm) and chlorophyll content (57.97), yield attributes *viz,* number of grains spike^{-1} (47.68) were recorded significantly higher under (M_2) Line sowing methods which was statistically at par with (M_3) Criss-cross method. While, number of tillers (350.01 m^{-2}), dry matter accumulation (561.75 g m^{-2}), crop growth rate (2.23 g m^{-2} day^{-1}) and yield attributes *viz,* number of effective tillers (241.28 m^{-2}) were recorded with (M_3) Criss-cross method which was statistically at par with (M_2) Line sowing method. Significantly higher grain yield (2919 kg ha^{-1}), straw yield (6438 kg ha^{-1}) and biological yield (9357 kg ha^{-1}) were recorded under (M_3) Criss-cross method. Among the fertility levels, significantly higher growth parameters *viz,* plant height (81.98 cm), chlorophyll content (58.30), number of tillers (279.48 m^{-2}), dry matter accumulation (593.21 g m^{-2}), crop growth rate (1.90 g m^{-2} day^{-1}), yield attributes *viz,* number of grains spike^{-1} (46.28), number of effective tillers (240.76 m^{-2}) and grain yield (3066 kg ha^{-1}), straw yield (7079 kg ha^{-1}) and biological yield (10145 kg ha^{-1}) were recorded under application of (N_2) 125% RDF which was statistically at par with application of (N_3) 100% RDF. Economically, (M_3) Criss-cross sowing recorded the significantly higher gross returns (₹ 83288 ha^{-1}), net returns (₹ 48559 ha^{-1}) and B:C ratio (1.38). While, significantly higher gross returns (₹ 88153 ha^{-1}) and net returns (₹ 47346 ha^{-1}) were recorded with application of (N_2) 125% RDF. However, highest B:C ratio (1.25) was recorded with application of (N_3) 100% RDF in Himachal Pradesh.

Keywords: Sowing methods, crop growth, agricultural economics, wheat production

Introduction
Wheat (*Triticum aestivum* L.) is the second most important cereal crop in the world after Rice. It provides 28% of the world's edible dry matter and up to 60% of daily calories in developing countries (Cakmak, 2008) [4]. Nutritionally, wheat has almost 1-1.5% fat, 2-2.5% fibre, 8-15% protein and 62-70% carbohydrates and provides 73% of calories in human diet (Malik *et al.*, 2021) [11].

Improper use of fertilizers, lack of information on variants, edaphic features, mismanagement of field operations and technology (Ali *et al.,* 2018; Prasad, 2012) [2, 16] affect the production of wheat crop. The use of optimum dose of fertilizer and suitable sowing method are essential for improving the yield of wheat. Application of NPK in balanced level has great impact on wheat yield. High yielding wheat varieties have been found highly responsible to nitrogen fertilization (Gupta *et al.*, 2016) [6]. The efficiency of both nitrogen and phosphorus is greatly enhanced in the presence of each other (Stoeva and Tonev, 2003) [24]. Increased use of nitrogen without adding potassium that is required in soil has further aggravated potassium deficiency because potassium play important role in improvement of the growth indices of crop (Singh *et al.,* 2018) [22]. Abd El-Lattie (2014) [1] reported that sowing methods played an important role in the placement of seed at proper depth and stand establishment of the growing crop which ultimately affects crop

growth and productivity. Appropriate sowing method is one of the important agronomic approaches that can be used to enhance wheat yield by optimizing tillering capacity and the efficient utilization of other available resources (Mehmood *et al.,* 2012) [12]. Sowing methods guarantee proper crop establishment and most favourable plant population in the field, as well as facilitating plants to utilize the land and other resources more efficiently and decisively toward growth and development (Singh *et al.,* 2019) [18].

With regard to fertilizers, they are an integral part of the modern crop-production technology (Tariq *et al.,* 2007) [25] but the balanced use of fertilizers is considered one of the important keys to get bumper crop harvest (Singh *et al.,* 2012) [21]. The imbalanced use of fertilizers particularly nitrogen, phosphorus and occasionally potassium leads to a major constraint in harvesting the potential yields of the crop **(**Kenedy *et al.,* 2012) [9].

Materials and Methods

The field experiment was conducted during *rabi* season of 2023-24 at Chamelti Agriculture Farm (1,270 meters above mean sea level lying between latitude 300 85'67.30 N and longitude 770 13'20.38 E), MS Swaminathan School of Agriculture, Shoolini University, Solan, Himachal Pradesh. This mid-hill region falls under moist sub humid zone of Himachal Pradesh. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction with EC in safer range, medium in organic carbon, available nitrogen, available potassium and high in available phosphorus. The field experiment was laid out in split plot design comprising twelve treatments combinations with three replications. The experiment consists of three sowing methods in main plot i.e. (M_1) Broadcasting, (M_2) Line sowing and (M_3) Criss-cross. Each main plot was further divided into four sub plots to accommodate sub plot treatments *viz.*, (N_1) Control, (N_2) 125% RDF, (N_3) 100% RDF and (N_4) 75% RDF in sub plot. Recommended dose of fertilizers was used 120:60:30 kg NPK ha^{-1} in test crop. Full dose of phosphorus, potassium and half dose of nitrogen was applied through urea, SSP and MOP at the time of sowing as basal application and remaining half nitrogen was applied in two equal splits at CRI and tillering stage. Methods of sowing adopted and fertilizers were applied as per treatment. HPW-368 variety of wheat was used for sowing. Other crop management practices were followed as per the recommendation of the area. Observations related to growth characters, yield attributes and yield was taken as per standard procedure. However, economics was calculated as per standard formula on hectare basis. The treatments difference was compared with the critical difference (CD) at 5% level of significance to ascertain their significance.

Results and Discussion

Effect on crop growth characters

Marked variation in crop growth characters were recorded with different sowing methods and fertility levels. Significantly higher plant height (81.34 cm) and chlorophyll content (57.97 SPAD value) were recorded under (M_2) Line sowing which was statistically at par with (M_3) Criss-cross method of sowing at harvest. However, number of tillers (350.01 m^{-2}), dry matter accumulation (561.75 g m^{-2}) and crop growth rate (2.23 g m^{-2} day^{-1}) were significantly higher under (M_3) Criss-cross method.

In case of fertility levels, significantly higher plant height (81.98 cm), chlorophyll content (58.30 SPAD value), number of tillers (279.48 m^{-2}), dry matter accumulation (593.21 g m^{-2}) and crop growth rate (1.90 g m^{-2} day^{-1}) were recorded under the application of (N_2) 125% RDF which was statistically at par with (N_3) 100% RDF over rest of the lower levels.

Interaction between sowing methods and fertility levels could not reach to level of significance.

This might be due to sowing with proper method of sowing allows for sufficient aeration, moisture, sunlight and nutrient availability, leading to proper root system development from the early stage of crop growth which enhanced the plant height. Same findings are also reported by Singh *et al.* (2015) [23]; Singh and Chaturvedi (2022) [20]. Increase in plant height, number of tillers, chlorophyll content, dry matter accumulation and crop growth rate by wheat by increase in nutrients level were also noticed Jat *et al.* (2013) [8]; Mishra *et al.* (2021) [13].

Effect on yield attributes

Different sowing methods and fertility levels exerted significant effect on yield attributes except for spike length and test weight. Among the sowing methods, (M_2) Line sowing recorded significantly higher number of grains $spike^{-1}$ (47.68) which was statistically at par with (M_3) Criss-cross method of sowing. However, significantly higher number of effective tillers (241.28 m^{-2}) was recorded under (M_3) Criss-cross sowing which was statistically at par with (M_2) Line sowing. In criss-cross sowing plants utilized all the available resources more efficiently for producing more ear bearing tillers per unit area. The results were also reported by Pandey and Kumar (2005) [15].

In case of fertility levels, application of (N_2) 125% RDF recorded significantly higher number of grains $spike^{-1}$ (46.28), number of effective tillers (240.76 m^{-2}) which was statistically at par with application of (N_3) 100% RDF. Positive effect of fertility levels were noticed on yield attributes (number of grains $spike^{-1}$ and number of effective tillers) due to the increasing NPK level up to 25% from recommended dose. Nitrogen is an important constituent of chlorophyll and so, if applied adequately stimulates photosynthetic in plants. This resulted in production of higher number of tillers with more number of grains $spike^{-1}$. Phosphorus is essential in laying down the primordial for the reproductive parts of the plants. Higher level of potassium application under 125% RDF might be due to its greater removal and active participation in all structure, carbon assimilation, photosynthesis, starch formation, translocation of protein and sugar, entry of water into plants root and development etc. adequate supply of potassium was responsible for better performance of yield attributes. Same findings were also observed by Jat *et al.* (2013) [8].

Effect of yield (Kg ha^{-1})

Significantly higher grain (2576 Kg ha^{-1}), straw (3778 Kg ha^{-1}) and biological yield (6354 Kg ha^{-1}) of wheat was recorded under (M_3) Criss-cross sowing method. In case of fertility levels, significantly higher grain (2716 Kg ha^{-1}), straw (4048 Kg ha^{-1}) and biological yield (6764 Kg ha^{-1}) was recorded under application of (N_2) 125% RDF which was statistically at par with application of (N_3) 100% RDF. Harvest index was not exerted by methods of sowing and fertility levels. The interaction effect of both treatments was found to be non-significant.

Criss-cross sowing appears to produce significantly more straw yield than other sowing methods due to better dry matter production at various growth stages, while improvements in both grain and straw yield produced higher biological yield. The current findings of study, which shows that criss-cross sowing produces greater yield than other methods, support those of other studies Singh *et al.* (2020) [19] and Bhaskar *et al.* (2022) [3].

Yield attributes have the direct effect on grain and straw yield. The improvement of grain and straw yield due to growth, yield attributing characters and also higher photosynthesis activities at higher level of fertility (125% RDF). Continuous supply of nutrients in balanced quantity throughout the various growth stages enables the plants to assimilate sufficient photosynthetic product and thus increased dry matter accumulation. With increased dry matter and photosynthetic products coupled with efficient translocation, basic characteristics of such plant types, plant produced more panicles with more number of effective grains as a result higher grain yield was recorded at higher level of fertility. Increase in grain and straw yield with increasing NPK level have also reported by Jat *et al.* (2013) [8]; Singh *et al.* (2018) [22].

Effect on Economics

Different sowing methods and fertility levels exerted significant effect on economics of wheat. Among the sowing methods, significantly higher gross returns (₹ 83288 ha^{-1}), net returns (₹ 48559 ha^{-1}) and B:C ratio (1.38) recorded under the (M_3) Criss-cross method was statistically at par (M_2) Line sowing method. In case of fertility levels, significantly higher gross returns (₹ 88153 ha^{-1}) and net returns (₹ 47346 ha^{-1}) were recorded under application of (N_2) 125% RDF. However, highest B:C ratio (1.25) was recorded under application of (N_3) 100% RDF which was statistically at par with rest of the treatments except (N_1) Control. The interaction between both treatments was found to be non-significant.

This might be due to the higher grain yield and straw yield in the criss-cross method compared to other methods of sowing. Same results were also found by Singh *et al.* (2018) [22].

In case of fertility levels, (N_2) 125% RDF gave the higher gross and net returns this might be due to the higher grain yield and straw yield. Similar finding were also reported by Gupta *et al.* (2011) [7]; Dhaker *et al.* (2022) [5]; Kumari *et al.* (2022) [10]; Sadineni *et al.* (2021) [17]; Muchhadiya *et al.* (2021) [14].

Table 1: crop growth characters of wheat as influenced by sowing methods and fertility levels at harvest

Treatments	Crop growth characters				
	Plant height (cm)	Chlorophyll content (SPAD value) at 150 DAS	Number of tillers (m^{-2})	Dry matter accumulation (g m^{-2})	Crop growth rate (g m^{-2} day^{-1}) at 150 DAS- at harvest
Main plot (Sowing methods)					
M_1: Broadcasting	63.20	48.11	214.15	399.19	1.08
M_2: Line sowing	81.34	57.97	241.14	500.37	1.88
M_3: Criss cross	77.40	53.72	350.01	561.75	2.23
S.Em±	1.77	1.17	5.06	11.90	0.05
LSD (*p*=0.05)	6.95	4.58	19.88	46.74	0.19
Sub plots (Fertility levels)					
N_1: 0 (control)	62.79	48.48	255.34	297.53	1.41
N_2: 125% RDF	81.98	58.30	279.48	593.21	1.90
N_3: 100% RDF	78.97	55.46	273.62	567.74	1.85
N_4: 75% RDF	72.19	50.82	265.29	489.92	1.76
S.Em±	1.71	1.16	4.60	10.18	0.04
LSD (*p*=0.05)	5.07	3.45	13.67	30.26	0.13
Interaction (M*N)	NS	NS	NS	NS	NS

Table 2: Yield attributes of wheat as influenced by sowing methods and fertility levels at harvest

Treatments	Yield attributes			
	Spike length (cm)	Number of grains $spike^{-1}$	Number of effective tillers (m^{-2})	Test weight (g)
Main plot (Sowing methods)				
M_1: Broadcasting	14.68	37.17	206.96	37.10
M_2: Line sowing	16.19	47.68	226.59	40.15
M_3: Criss cross	15.94	45.37	241.28	38.31
S.Em±	0.34	0.99	5.18	0.85
LSD (*p*=0.05)	NS	3.88	20.32	NS
Sub plots (Fertility levels)				
N_1: 0 (control)	14.99	38.76	201.69	37.55
N_2: 125% RDF	16.34	46.28	240.76	39.17
N_3: 100% RDF	15.78	45.66	236.99	38.91
N_4: 75% RDF	15.57	42.93	220.34	38.45
S.Em±	0.33	0.92	5.15	0.74
LSD (*p*=0.05)	NS	2.72	15.29	NS
Interaction (M*N)	NS	NS	NS	NS

Table 3: Yield (Kg ha^{-1}) of wheat as influenced by sowing methods and fertility levels at harvest

Treatments	Yield (Kg ha^{-1})			Harvest index (%)
	Grain yield	Straw yield	Biological yield	
Main plot (Sowing methods)				
M_1: Broadcasting	2162	5547	7709	28.06
M_2: Line sowing	2610	6339	8949	29.10
M_3: Criss cross	2919	6438	9357	31.10
SEm±	71	173	241	0.78
LSD (*p*=0.05)	280	679	947	NS
Sub plots (Fertility levels)				
N_1: 0 (control)	1721	4341	6062	28.54
N_2: 125% RDF	3066	7079	10145	30.07
N_3: 100% RDF	2889	6857	9746	29.64
N_4: 75% RDF	2577	6155	8732	29.43
SEm±	65	172	240	0.46
LSD (*p*=0.05)	192	511	713	NS
Interaction (M*N)	NS	NS	NS	NS

Table 4: Economics (₹ ha^{-1}) of wheat as influenced by different fertility levels and sowing methods at harvest

Treatments	Economics (₹ ha^{-1})			B:C ratio
	Cost of cultivation	Gross returns	Net returns	
Main plot (Sowing methods)				
M_1: Broadcasting	32279	59770	27491	0.85
M_2: Line sowing	32854	73787	40933	1.23
M_3: Criss cross	38729	83288	48559	1.38
SEm±	-	1775	1775	0.06
LSD (*p*=0.05)	-	6969	6969	0.24
Sub plots (Fertility levels)				
N_1: 0 (control)	22008	44771	22763	1.03
N_2: 125% RDF	40806	88153	47346	1.15
N_3: 100% RDF	37047	83561	46514	1.25
N_4: 75% RDF	33287	72642	39355	1.18
SEm±	-	1673	1673	0.05
LSD (*p*=0.05)	-	4970	4970	0.15
Interaction (M*N)	-	NS	NS	NS

Conclusion

On the basis of present experimentation it is to be concluded that Criss-cross sowing method along with 125% RDF recorded significant improvement in growth, yield attributes and yield of wheat which was statistically at par with Line sowing method. Economically application of 100% RDF with Criss-cross sowing remunerative for wheat crop under mid hills of Himachal Pradesh.

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