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Effect of sowing methods, seed rates and nutrient management on productivity and profitability of wheat (*Triticum aestivum* L.) in northern-hill zone of Chhattisgarh

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Abstract
A field experiment was carried out for two consecutive years in *rabi* seasons of 2017-18 and 2018-19 at Research Cum Instructional Farm, IGKV, Lt. Dr. Ramchanra Singh Dev College of Agriculture and Research Station, Baikunthpur, Korea, Chhattisgarh. The soil of experimental field was (Vertisols), neutral in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in Split Plot Design with three replications. The main- plot treatment consisted of 02 Sowing methods *i.e.* A_1: Line sowing, A_2: Criss-cross sowing, Seed rates (03) B_1: 100 kg ha^{-1}, B_2: 150 kg ha^{-1}, B_3: 200 kg ha^{-1}, Sub-plot: Nutrient management (03) N_1: RDF 100%, N_2: RDF 150%, N_3: STCR (4 t Targeted yield). The wheat variety GW-366 was sown as test crop during 27th November, 2017-18 and 30th November 2018-19. Harvesting was done during 18th April in the first year (2018) and 20th April in the second year (2019), respectively. Observations on various growth and yield attributes, grain and straw yields, economics were recorded and data were analyzed statistically.

Keywords: Wheat, sowing methods, seed rate and nutrient levels, yield attributes and yield

Introduction
Wheat is one of the most important cereal crops of the world occupying around 217 million hectares holding with a production of 713 million tonnes and productivity of 3371kg ha^{-1}. Nearly 55 per cent of the world population depends on wheat for about 20 per cent of calories intake. India is second largest producer of wheat in the world after China with about 12 per cent share in total world production. In India, wheat is second most important food crop, next to rice, with an area of 31.62 million hectares and production of 109.52 million tons (Anonymous, 2021) [4]. In Chhattisgarh, wheat is cultivated in an area of 3.6 million hectare with the productivity of the state ranging between 1.2 to 1.6 t ha^{-1} depending upon the rainfal. In the Northern-Hills Zone of Chhattisgarh especially Baikunthpur, Surajpur, Ambikapur and other in other districts wheat is a major cereal crop of *rabi* season in rice based cropping system under irrigated condition and maximum farmers grow wheat crop after harvesting of rice in midland condition. The climatic condition is quite favorable for wheat cultivation due to prolong & cold winter. The productivity of the wheat depends upon on several factors like crop establishment techniques, irrigation; weed management, sowing methods, seed rate, fertilizers management and other cultural practices. The method of sowing is significant as it determines the proper crop stand establishment and the production of individual plant depends on balancing plant to plant competition. In India especially in Chhattisgarh, wheat is planted through broadcasting on a large area after rice harvesting. Broadcasting not only requires higher seed rate but also results in lower plant population, whereas drill sowing method is recommended because of its uniform seed distribution and sowing at desired depth, which usually results in higher germination and uniform stand. A key factor in the highest wheat production is the understanding of an early crop establishment. Beside other agronomic factors seed rate and sowing method are major factors which determines the crop vigor and ultimate yield (Korres and Froud, 2000) [12]. The maintenance of optimum plant stand with the use of optimum seed rate and appropriate sowing method is of prime importance for exploiting available resources (below and above ground) towards yield formation. Normal seed rate results in lower yield than higher seed rate under late sown conditions. Yield in wheat is dependent mainly on the number of spikes per unit area and average seed yield per spike, where the number of spikes per unit area can well be compensated by using higher seed rate as practiced in several other wheat growing parts of the world.

Plant density is a major factor determining the ability of the crop to capture resources and generate yield. It can be developed by using a suitable seeding rate. Growth and yield of wheat are affected by environmental conditions and can be regulated by sowing time and seeding rate (Ozturk *et al*., 2006) [15].

The aim of nutrient management to provide an adequate supply of all essential plant nutrients for a crop growth during the growing season and the amount of any nutrient is limiting at any time which is a potential for loss in crop yield. In many areas, crop yield started declining because a reduction in factor productivity and farmers have resorted to using higher dose of fertilizers than recommended doses of fertilizer (RDF) to maintain previously achieved yield levels. RDF play an important role for enhancing the production of crop, but continuous and inappropriate use of chemical fertilizers which adversely affect the production potential and soil health (Sharma *et al.,* 2003) [18]. Nutritional management is also one of the important factors identified for improving wheat productivity. Therefore, the easiest way for increasing the production and productivity of the crop is through use of balanced fertilization. But even today, most of the farmers in this region are usually applying higher dose of nitrogen, low phosphorus and no potassic fertilizers at all which grossly imbalance the ratios of N, P and K. On the other the hand, balanced fertilizer is the application of essential plant nutrients in the right proportion and in optimum quantity for a specific- crop condition. Continuous imbalanced use of fertilizer leads to deterioration soil fertility and decrease soil productivity (Jaga and Upadhyay, 2013) [9]. Integrated plant nutrient supply system can help in meeting the goal of balanced fertilization (Chatterjee *et al*., 2010) [6]. The practice of nutrient application based on STCR fertilizer recommendations for targeted yield using developed fertilizer adjustment equations for crops provides better option for balanced application of nutrients. The present investigation was carried out to study the effect of STCR based fertilizer recommendations on yield, economics and changes in soil properties under pearl millet - wheat cropping sequence.

Material and Methods

A field experiment was carried out for two consecutive years in *rabi* seasons of 2017-18 and 2018-19 at Research Cum Instructional Farm, IGKV, Lt. Dr. Ramchanra Singh Dev College of Agriculture and Research Station, Baikunthpur, Korea, Chhattisgarh. The soil of experimental field was (Vertisols), neutral in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in Split Plot Design with three replications.

The main- plot treatment consisted of 02 Sowing methods, (03) Seed rates, Sub-plot: (03) Nutrient management. The wheat variety GW-366 was sown as test crop during 27th November, 2017-18 and 30th November 2018-19. Harvesting was done during 18th April in the first year (2018) and 20th April in the second year (2019), respectively. Observations on various growth and yield attributes, grain and straw yields, economics were recorded and data were analyzed statistically. The temperature of Korea district remains moderate throughout the year, except from March to June, in this month temperature remains extremely hot. The maximum weekly temperature of Korea district goes up to 45.2 ^{o}C in the month of May. Whereas, minimum temperature falls up to 9 ^{o}C in the month of January. Winters starts from November to January and are mild. The average annual rainfall varies between 1200-1400 mm, which is mostly received during a span of four months *i.e.* between June to September through south-western monsoon. The wheat variety GW-366 was sown as test crop during 27th November, 2017-18 and 30th November 2018-19. Harvesting was done during 18th April in the first year (2018) and 20th April in the second year (2019), respectively.

Result and Discussion

Yield attributes

Number of effective tillers m^{-2}

Number of effective tillers per unit area is one of the important yield attributing components which affects the photosynthetic efficiency of the plant. As the number of effective tillers per plant increases, the yield per hectare also increases. The data regarding number of effective tillers m^{-2} are presented in Table 1

The number of effective tillers m^{-2} was significantly affected due to different sowing methods during both the years and on mean basis. The significantly higher number of effective tillers m^{-2} was recorded in treatment A_2: criss-cross sowing as compared to treatment A_1: line sowing methods during both the years and on mean basis. In criss-cross sowing plants utilized all the available resources more efficiently for producing more ear bearing tillers per unit area. The result concurs with the findings of Pandey and Kumar (2005) [16].

As regards to seed rates in wheat, treatment B_2: 150 kg ha^{-1} registered significantly higher number of effective tillers m^{-2} as compared to other treatments. The significantly lowest number of effective tillers m^{-2} was noted under B_1: 100 kg ha^{-1} during both the years and on mean basis. High plant density beyond optimum level leads to mutual competition among plants due to which it fails to exploit the inputs fully. Similar results have been reported by other researchers Arduini *et al*. (2006) [5].

Among different nutrient management, crop fertilized with N_3: STCR (4 t targeted yield) gave the maximum number of effective tillers during both the years and on mean basis. The minimum number of effective tillers m^{-2} recorded under N_1: RDF 100% during both the years and on mean basis. The better growth parameters of wheat resulted in enhanced photosynthesis and thus gave higher values of yield attributes with STCR as direct effect. Similar results were also reported by Mauriya *et al*. (2013) [13].

The interaction effect between sowing methods and seed rate on number of effective tillers m^{-2} was of wheat was found significant during both the years and on mean basis and data are presented in Table 2. The findings revealed that the interaction between A_2: criss-cross sowing and B_2: 150 kg ha^{-1} registered significantly higher number of effective tillers m^{-2} as compared to other interactions. However, it was statistically at par to treatment A_2: criss-cross sowing and B_3: 200 kg ha^{-1} during both the years and on mean basis.

Earhead length (cm)

The length of ears is one of the yield attributes of wheat that contribute to grain yield. Crops with lengthier ears could have higher grain yield. Data on length of ears (cm) as influenced by sowing methods, seed rate and nutrient management have been presented in Table 1.

A critical examination of the data on length of ears revealed that among the sowing methods, significantly higher ear length was recorded under treatment A_2: criss-cross sowing as compared to treatment A_1: line sowing methods during both the years and on mean basis.

As regards to seed rate, significantly higher ear length was recorded under the treatment B_2: 150 kg ha^{-1} as compared to other treatment and the lowest length of earhead (cm) was noted under B_1: 100 kg ha^{-1} during both the years and on mean basis.

As regards to the effect of nutrient management, significantly the maximum length of ear was appeared in wheat plants supplied with N_3: STCR (4 t targeted yield) which was significantly lengthier when compared to other treatment during both the years and on mean basis. The minimum length was obtained by treatment of N_1: RDF 100% during both the years and on mean basis.

The interactions among sowing methods, seed rate and nutrient management were noted to be non-significant with regards to earhead length during both the years and on mean basis.

Number of grains earhead^{-1}

Number of grains earhead^{-1} has been considered as a main yield component which defines the yield potential of crop. Data recorded on the number of grains earhead^{-1} as affected by sowing methods, seed rate and nutrient management have been presented in Table 1.

In respect to sowing methods in wheat, the significantly higher number of grains earhead^{-1} was recorded under the treatment A_2: criss-cross sowing as compared to treatment A_1: line sowing methods during both the years and on mean basis.

Data further showed that number of grains earhead^{-1} of wheat differed significantly during both the years and on mean basis. It is evident that number of grains head^{-1} of wheat enhanced up to the seeding rate of B_1:100 kg ha^{-1} and thereafter reduced drastically in response to higher seeding rates. The maximum number of grains earhead^{-1} was obtained from the crop seeded with B_1: 100 kg ha^{-1} seed rate which was significantly higher than those produced by lower and higher seeding rates. The lowest number of grains earhead^{-1} was recorded under seed rate of B_3: 200 kg ha^{-1} during both the years and on mean basis. The reduced grains per ear head with optimum seeding rate might be due to less competition among the plants for light, moisture and nutrients compared with those at higher seed rate. Furthermore, the mutual competition among plants at higher seed rate decreased grains spike^{-1} and 1000-grain weight. Similar results have also been reported by Ali *et al.* (2010) [2].

Data in similar table further revealed that balanced levels of nutrient management brought about the significantly highest the number of grains head^{-1} tretment N_3: STCR (4t targeted yield) during both the years and on mean basis. The lowest number of grains earhead^{-1} was recorded under seed rate of N_1: RDF 100% during both the years and on mean basis. The better growth parameters of wheat resulted in enhanced photosynthesis and thus gave higher values of yield attributes with STCR as direct effect. Similar results were also reported by Mauriya *et al.* (2013) [13].

Interactions among sowing methods, seed rate and nutrient management on the number of grains earhead^{-1} were noted to be non-significant during both the years and on mean basis.

Grain weight earhead^{-1}(g)

The data on grain weight earhead^{-1} was significantly influenced by sowing methods, seed rate and nutrient management during both the years and on mean basis and presented in Table 2.

Among different sowing methods, A_2: criss-cross sowing gave significantly higher grain weight earhead^{-1} as compared to treatment A_1: line sowing method during both the years and on mean basis.

Different seed rates caused significant variation in the grain weight earhead^{-1} of wheat during both the years and on mean basis. Among the seed rates, significantly highest grain weight earhead^{-1} was recorded under treatment B_1: 100 kg ha^{-1}, were the lowest grain weight earhead^{-1} was recorded under treatment B_3: 200 kg ha^{-1} during both the years and on mean basis. The higher level of seed rate decreased the grain weight earhead^{-1} owing to the poor photosynthesis, which was largely accounted by the smaller grains. These results are in line with the findings of Hussain *et al.* (2006) [8].

Data reveals that balanced levels of nutrient management brought about significantly, the highest grain weight earhead^{-1} under treatment N_3: STCR (4t targeted yield) during both the years and on mean basis. The lowest grain weight earhead^{-1} was noted under treatment N_1: RDF 100% during both the years and on mean basis. This may be due to more absorption and utilization of available nutrients leading to overall improvement of crop growth and source-sink relationship, which in turn enhanced the yield attributes and yield of wheat under STCR approach. This result was in accordance with the findings of Rawal *et al.* (2017) [17].

The interaction effect among sowing methods and seed rates on the grain weight earhead^{-1} of wheat was found to be significant during both the years and on mean basis (Table 4). The significantly maximum grain weight earhead^{-1} was recorded under interaction between A_2: criss-cross sowing and B_1: 100 kg ha^{-1} during both the years and on basis.

Test weight (g)

The data on 1000-grains weight (g) of wheat as influenced by different treatments sowing method, seed rate and nutrient management during both the years and on mean basis have been presented in Table 4.3.

Different sowing methods, significantly influenced the 1000-grains weight during both the years and on mean basis. The significantly maximum 1000-grains weight was produced under treatment A_2: criss-cross sowing whereas, significantly the lighter 1000-grains weight was noted under A_1: line sowing methods during both the years and on mean basis. The greater 1000-grain weight in criss-cross methods might be due to better stand establishment and less plant competition for light, air and nutrients necessary for plant growth and development. Our results are in line with previous findings of Khan *et al.* (2007) [11].

As regards to seed rates in wheat, treatment B_1: 100 kg ha^{-1} registered significantly the highest 1000-grains weight during both the years and on mean basis. The lighter 1000-grains weight was recorded under B_3: 200 kg ha^{-1} during both the years and on mean basis. An increase in test weight in plots sown at the seeding rate of 100 kg ha^{-1} might be due to the maximum light interception at this rate and so wheat produced the heaviest grains (Amanullaha *et al.*, 2010) [3].

A perusal of data revealed that nutrient management showed the significant effects on 1000-grain weight of wheat during both the years. The heaviest 1000- grain weight was observed wherein crop received N_3: STCR (4t targeted yield) during both the years and on mean basis. The lowest 1000- grain weight was recorded under seed rate treatment B_3: 200 kg ha^{-1} during both the years and on mean basis. The STCR based treatments significantly increased test weight as compared to other treatments. Similar trends of results were reported by Kumar (2011).

The interactions among sowing method, seed rates and nutrient management were noted to be non-significant during both the years and on mean basis.

Table 1: Yield attributes of wheat as influenced by sowing methods, seed rate and nutrient management

Treatment	Number of effective tillers m^{-2}			Earhead length (cm)			Grains earhead^{-1} (no.)		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Sowing methods									
A1: Line sowing	328.15	331.97	330.06	8.49	8.86	8.68	43.83	45.33	44.58
A2: Criss-cross sowing	356.30	361.17	358.73	9.11	9.48	9.29	45.74	47.37	46.55
SEm±	0.967	0.840	0.777	0.043	0.054	0.044	0.214	0.342	0.525
CD (P=0.05)	3.044	2.644	2.446	0.135	0.171	0.140	0.674	1.076	0.793
Seed rate (kg ha^{-1})									
B1: 100	303.84	308.54	306.19	9.72	9.98	9.85	48.14	50.93	49.53
B2: 150	365.96	369.46	367.71	8.51	8.82	8.66	44.64	45.23	44.93
B3: 200	356.86	361	359.28	8.17	8.71	8.44	41.57	42.88	42.23
SEm±	1.184	1.028	0.951	0.053	0.067	0.054	0.262	0.418	0.309
CD (P=0.05)	3.729	3.239	2.996	0.166	0.209	0.171	0.825	1.318	0.972
Nutrient management									
N1: RDF 100%	328.93	334.54	331.73	8.57	8.99	8.78	44.18	47.73	44.96
N2: RDF150%	344.53	349.67	347.10	8.77	9.10	8.93	44.83	46.31	45.57
N3: STCR (4 t Targeted yield)	353.21	355.50	354.35	9.06	9.41	9.24	45.34	47.01	46.17
SEm±	5.390	5.605	5.478	0.036	0.054	0.040	0.105	0.227	0.129
CD (P=0.05)	15.737	16.364	15.993	0.106	0.157	0.116	0.307	0.662	0.376
Interaction, A x B	S	S	S	NS	NS	NS	NS	NS	NS

Table 2: Interaction effect of sowing methods and seed rate of wheat on number of effective tillers m^{-2}

Treatment	Number of effective tillers m^{-2}								
	2017-18			2018-19			Mean		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
A1: Line sowing	277.94	362.18	344.32	282.40	364.93	348.60	280.17	363.56	346.46
A2: Criss-cross sowing	329.74	369.74	369.41	334.68	374.10	373.00	332.21	372.10	371.87
SEm±	1.674			1.454			1.227		
CD (P=0.05)	5.273			4.580			3.863		

Seed rate (kg.ha^{-1}) B1: 100, B2: 150 and B3: 200

Table 3: Yield attributes of wheat as influenced by sowing methods, seed rate and nutrient management

Treatment	Grain weight earhead^{-1}(g)			Test weight (g)		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Sowing methods						
A1: Line sowing	2.44	2.49	2.47	42.19	42.97	42.85
A2: Criss-cross sowing	2.77	2.81	2.79	43.64	44.57	44.11
SEm±	0.029	0.027	0.028	0.151	0.135	0.139
CD (P=0.05)	0.091	0.084	0.087	0.477	0.424	0.438
Seed rate (kg ha^{-1})						
B1: 100	3.12	3.16	3.14	46.23	47.13	46.68
B2: 150	2.54	2.59	2.57	42.99	43.80	43.39
B3: 200	2.15	2.20	2.18	39.53	40.40	39.96
SEm±	0.035	0.033	0.034	0.185	0.165	0.170
CD (P=0.05)	0.111	0.103	0.107	0.584	0.519	0.537
Nutrient management						
N1: RDF 100%	2.55	2.59	2.58	42.23	43.13	42.68
N2: RDF150%	2.55	2.60	2.58	42.99	43.80	43.39
N3: STCR (4 t Targeted yield)	2.71	2.75	2.73	43.53	44.40	43.96
SEm±	0.033	0.031	0.032	0.106	0.098	0.095
CD (P=0.05)	0.096	0.090	0.094	0.310	0.286	0.277
Interaction, A x B	S	S	S	NS	NS	NS

Table 4: Interaction effect of sowing methods and seed rate of wheat on grain weight earhead^{-1} (g)

Treatment	Grain weight earhead^{-1}(g)								
	2017-18			2018-19			Mean		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
A1: Line sowing	2.83	2.41	2.08	2.88	2.45	2.13	2.86	2.43	2.11
A2: Criss-cross sowing	3.41	2.68	2.22	3.44	2.72	2.27	3.43	2.70	2.25
SEm±	0.050			0.046			0.028		
CD (P=0.05)	0.157			0.146			0.151		

Seed rate (kg.ha^{-1}) B1: 100, B2: 150 and B3: 200

Table 5: Grain, straw yield of wheat as influenced by sowing methods, seed rate and nutrient management

Treatment	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Sowing methods									
A1: Line sowing	33.14	33.92	33.53	47.38	48.20	47.79	41.01	41.16	41.08
A2: Criss-cross sowing	37.08	37.98	37.53	51.00	51.73	51.36	42.00	42.22	42.11
SEm±	0.074	0.078	0.076	0.086	0.079	0.082	0.048	0.048	0.050
CD (P=0.05)	0.233	0.244	0.239	0.271	0.247	0.257	0.153	0.150	0.159
Seed rate (kg ha^{-1})									
B1: 100	30.35	31.09	30.72	44.67	45.51	45.09	40.30	40.43	40.36
B2: 150	38.33	39.25	38.79	52.21	52.97	52.59	42.30	42.52	42.41
B3: 200	36.65	37.50	37.08	50.68	51.42	51.05	41.92	42.12	42.02
SEm±	0.091	0.95	0.093	0.105	0.096	0.100	0.059	0.058	0.062
CD (P=0.05)	0.285	0.299	0.292	0.332	0.303	0.315	0.187	0.183	0.194
Nutrient management									
N1: RDF 100%	33.03	33.83	33.43	47.03	47.80	47.41	41.11	41.29	41.20
N2: RDF150%	35.43	36.28	35.85	49.53	50.33	49.93	41.55	41.73	41.64
N3: STCR (4 t Targeted yield)	36.08	37.73	37.30	51.00	51.77	51.39	41.85	42.05	41.95
SEm±	0.812	0.831	0.821	0.785	0.780	0.782	0.191	0.198	0.194
CD (P=0.05)	2.369	2.426	2.397	2.292	2.227	2.283	0.557	0.578	0.567
Interaction, A x B	S	S	S	S	S	S	S	S	S

Table 6: Interaction effect of sowing methods and seed rate of wheat on grain yield (q ha^{-1})

Treatment	Grain yield (q ha^{-1})								
	2017-18			2018-19			Mean		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
A1: Line sowing	27.60	37.31	34.50	28.31	38.16	35.30	27.95	37.73	33.53
A2: Criss-cross sowing	33.10	39.35	38.80	33.88	40.34	39.71	33.49	39.85	37.53
SEm±	0.128			0.134			0.131		
CD (P=0.05)	0.403			0.423			0.413		

Table 7: Interaction effect of sowing methods and seed rate of wheat on straw yield (q ha^{-1})

Treatment	Straw yield (q ha^{-1})								
	2017-18			2018-19			Mean		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
A1: Line sowing	42.19	51.21	48.74	43.05	52.02	49.53	42.62	51.62	49.14
A2: Criss-cross sowing	47.16	53.20	52.63	47.97	53.91	53.31	47.56	53.56	51.36
SEm±	0.149			0.136			0.141		
CD (P=0.05)	0.469			0.428			0.445		

Table 8: Interaction effect of sowing methods and seed rate of wheat on harvest index (%)

Treatment	Harvest index (%)								
	2017-18			2018-19			Mean		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
A1: Line sowing	39.49	42.12	41.42	39.61	42.28	41.58	39.55	42.20	41.50
A2: Criss-cross sowing	41.10	42.30	42.05	41.25	42.75	42.66	41.18	42.61	42.54
SEm±	0.084			0.082			0.087		
CD (P=0.05)	0.264			0.289			0.2775		

Seed rate (kg.ha^{-1}) B1: 100, B2: 150 and B3: 200

Grain yield (q ha^{-1})

The grains yield the ultimate result of various interacting growth factors, development and yield contributing characters. The data pertaining to grain yield of wheat as influenced by sowing method, seed rate and nutrient management are presented in Table 5.

Among sowing methods in wheat, significantly highest grain yield was recorded in treatment A_2: criss-cross sowing and the lowest grain yield were registered in treatment A_1: line sowing method during both the years and on mean basis. Higher yield under criss-cross and unidirectional sowing was also attributed owing to optimum number of plants per unit land area, which reduced weed infestation and provided conducive environment for proper growth and development of crop plant and yield attributes to the desirable extent. (Abbas *et al*., 2009) [1].

Data further explained that among different seed rate in wheat, significantly highest grain yield was recorded under treatment B_2: 150 kg ha^{-1} and the minimum grain yield were recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis. Grain yield and yield components at higher densities decreased, due to the change of resource allocation to storage organs under conditions of competition so when seed rate was increased harvest index was decreased. Similar finding was recorded by Meena and Singh (2011) [14].

Among nutrient management in wheat, significantly highest grain yield was recorded under treatment N_3: STCR (4t targeted yield) however, it was statistically at par to treatment N_2: RDF 150% during both the years and on mean basis. The minimum grain yield was recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis. The improvement in grain and straw yield of wheat crop using STCR based fertilizer recommendations may be attributed to balance supply of nutrients for wheat crop from soil and improvement in physical, chemical and biological properties of soil which is in agreement with the findings of Katkar *et al*. (2011) [10] and Yadav *et al*. (2005) [20].

Interaction effects of sowing methods and seed rate were found to be significant for grain yields of wheat during both the years and on mean basis (Table 6). Significantly maximum grain yield was recorded under interaction between A2: criss-cross sowing and B_2: 150 kg ha^{-1} during both the years and on mean basis. The results indicate that proper seed rate and sowing method increased plant vitality and yield as it encourages nutrient availability, proper sunlight penetration for photosynthesis. This increase in yield was associated with the progressive increase in all growth components. These results are in conformity with those of Soomro *et al*. (2009) [19] and El-Lattief (2011) [7].

Straw yield (q ha^{-1})

The straw yield (q ha^{-1}) is the ultimate result of various interacting growth factors, development and yield contributing characters. The data pertaining to straw yield of wheat (q ha^{-1}) as influenced by sowing method, seed rate and nutrient management are presented in Table 5.

Sowing methods in wheat significantly influenced the straw yield of wheat during both the years and on mean basis. The significantly highest straw yield was recorded in treatment A_2: criss-cross sowing and the lowest straw yield was registered in treatment A_1: line sowing method during both the years and on mean basis.

Data further explained that among different seed rate, significantly the highest straw yield was recorded under treatment B_2: 150 kg ha^{-1} and the minimum straw yield was recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis.

Among nutrient management in wheat, significantly the highest straw yield was recorded under treatment N_3: STCR (4t targeted yield), however, it was statistically at par to treatment N_2: RDF 150% during both the years and on mean basis. The minimum straw yield was recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis. The increase in straw yield with increase in seed rate was also reported by earlier researcher Ali *et al.* (2010) [2].

Interaction effects among sowing methods and seed rate in wheat, were found to be significant with respect to straw yield during both the years and on mean basis (Table 7). Significantly maximum straw yield was recorded under interaction between A_2: criss-cross sowing and B_2: 150 kg ha^{-1} during both the years and on mean basis.

Harvest index (%)

The ability of the crop to convert the total dry matter into economic yield is indicated by its harvest index value. Higher the harvest index value, greater is the physiological potential for converting the total dry matter in to grain yield. The data on harvest index as influenced by different treatments is presented in Table 5.

Sowing methods in wheat significantly influenced the harvest index of wheat during both the years and on mean basis. The significantly highest harvest index was recorded in treatment A_2: criss-cross sowing and the lowest harvest index was registered in treatment A_1: line sowing method during both the years and on mean basis.

Data further explained that among different seed rate, significantly highest harvest index was recorded under treatment B_2: 150 kg ha^{-1} and the minimum harvest index was recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis.

Among the nutrient management in wheat, significantly highest harvest index was recorded under treatment N_3: STCR (4t targeted yield), however, it was statistically at par to treatment N_2: RDF 150% during both the years and on mean basis. The minimum harvest index was recorded under B_1: 100 kg ha^{-1} during both the years and on mean basis.

Interaction effects between sowing methods and seed rate in wheat were found to be significant with respect to harvest index during both the years and on mean basis (Table 8). Significantly maximum harvest index was recorded under interaction between A_2: criss-cross sowing and B_2: 150 kg ha^{-1} as compared to other interactions. However, it was statistically at par to interaction between A_2: criss-cross sowing and B_3: 200 kg ha^{-1} during both the years and on mean basis.

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