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Rohit Kumar Dhatwalia
MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Kartikeya Choudhary
[1] MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India
[2] School of Agriculture, Galgotias University, Greater Noida, Uttar Pradesh, India

Rajni Devi
MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Corresponding Author:
Rohit Kumar Dhatwalia
MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Effect of fertility levels and sowing methods on wheat yield, nutrient content and soil nutrient availability under mid-hills of Himachal Pradesh

Rohit Kumar Dhatwalia, Kartikeya Choudhary and Rajni Devi

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Abstract
The present experiment titled "Effect of Fertility Levels and Sowing Methods on Wheat Yield, Nutrient Content and Soil Nutrient Availability under Mid-hills of Himachal Pradesh" was conducted during *rabi* season of 2023-24 at Chamelti Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University, Solan, Himachal Pradesh located at an elevation of 1,270 meters above mean sea level lying between latitude 300 85'67.30 N and longitude 770 13'20.38 E. Results indicated that among the sowing methods, significantly higher nutrient content in grain (1.92, 0.426 and 0.49%, NPK, respectively) and in straw (0.42, 0.185 and 1.27%, NPK, respectively) were recorded under Line sowing method. However, significantly higher nutrient uptake by grain (45.12, 10.76 and 11.95 Kg ha^{-1}, NPK respectively), nutrient uptake by straw (15.17, 7.12 and 52.84 Kg ha^{-1}, NPK respectively), [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 nutrient content in grain (1.90, 0.464 and 0.49%, NPK respectively), nutrient content in straw (1.64, 0.241 and 1.36%, NPK respectively), nutrient uptake by grain (51.60, 12.68 and 13.05 Kg ha^{-1}, NPK respectively), nutrient uptake by straw (18.73, 9.78 and 55.70 Kg ha^{-1}, NPK respectively), 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 treatment which was statistically at par with application of (N_3) 100% RDF under mid-hills of Himachal Pradesh.

Keywords: Wheat yield, nutrient content, nutrient uptake

Introduction

Wheat (*Triticum aestivum* L.), a member of the Gramineae family, is the second most important cereal crop in the world after Rice and it is emerged as the backbone of India's food security. Wheat is one of the main staple food worldwide which is available in various food forms and provides a large proportion of the world's nutrition compared to nutrition from other cereal grains (Uthayakumaran and Wrigley, 2010) [33]. It provides 28% of the world's edible dry matter and up to 60% of daily calories in developing countries (Cakmak, 2008). 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) [20].

Improper use of fertilizers, lack of information on variants, edaphic features, mismanagement of field operations and technology (Ali *et al.*, 2018; Prasad, 2012) [4, 23] affect the production of wheat crop. Fertilizers is one of the costly inputs that use for crop production, therefore, it is important to find out the way of economic use of fertilizer (Dhakal *et al.*, 2016; Kumat *et al.*, 2020) [11, 18]. The requirement for fertilizers for wheat depends on the accessibility of the crops to the soil (Krentos and Orphanos, 1979) [16]. Before using fertilizers, it is essential to recognize the condition of the soil's nutritional condition and plant nutrient uptake. The use of optimum dose of fertilizer and suitable sowing method are essential for improving the yield of wheat. Nitrogen is part of an essential component in cells, including amino acids, nucleic acid, photosynthesis pigment, protein and enzymes (Bungard *et al.*, 1999) [9]. The use of nitrogen enhances photosynthesis accumulation (Lawlor *et al.*, 1989). Nitrogen needs for cereals vary from different growth phases (Akhter *et al.*, 2016; Biljana and Aca, 2009) [3, 8]. Phosphorus is an essential part of numerous physiological functions such as energy accumulation and transmission, photosynthesis, respiration, cell differentiation, and cell expansion, which implies energy-rich phosphate compound synthesis as ATP, ADP.

Phosphoproteins, nucleic acids, nucleotides, phospholipids, are also essential components (Anwar, 2016) [54]. The concentration of potassium at the root and the plant surface determines potassium demand (Barnes *et al*., 1976) [6]. Potassium can significantly reduce the region of the upper leaves, depending on environmental factors and culture (Ralph and Ridgman, 1981) [25]. Until going for wheat the strongest demand is for potassium (Gasser and Thorburn, 1972) [12]. Wheat is like other field crops responding differently to various agro-management practices especially to sowing methods (Nasrullah *et al.*, 2010) [21]. Broadcasting is the most common sowing method adopted among the hill farmers which not only requires 20-25% extra seed but also results in erratic and non-uniform germination leading to poor crop stand. The broadcast sowing generally gives lower yield than sowing in rows (Krezel and Sobkowicz, 2013) [17]. Therefore, to ensure better and uniform germination and higher yield under rainfed conditions, it is necessary to have proper plant stand. Abd El-Lattie (2014) [2] 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. The line sowing is an another method of crop sowing which is a suitable alternative to broadcasting but the unavailability of a suitable sowing device limits its accessibility in hilly terrain. Though sowing methods plays a vital role in the productivity of wheat but it also depends upon several other factors like crop establishment techniques, irrigation, weed management, sowing methods, seed rate, fertilizer management and other cultural practices. With regard to fertilizers, they are an integral part of the modern crop-production technology (Tariq *et al.*, 2007) [31] but the balanced use of fertilizers is considered one of the important keys to get bumper crop harvest (Singh *et al.*, 2012) [29]. 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) [15].

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 combination 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. 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 yield, nutrient content and uptake was taken as per standard procedure. The treatments difference was compared with the critical difference (CD) at 5% level of significance to ascertain their significance.

Results and Discussion

Effect of yield (Kg ha^{-1}): Significantly higher grain (2576 Kg ha^{-1}), straw (3778 Kg ha^{-1}) and biological (6354 Kg ha^{-1}) yield 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 (6764 Kg ha^{-1}) yield 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 the factors 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) [18] and Bhaskar *et al.* (2022) [7]. The improvement of grain and straw yield due to growth, yield attributing characters and also higher photosynthesis activities at higher level of fertility i.e. (125% RD). 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) [14]; Singh *et al.* (2018) [26].

Effect on nutrient content (%) and their uptake (Kg ha^{-1}): Nutrient content in both grain and straw were significantly influenced by sowing methods and fertility levels.

Nitrogen content (%) and their uptake (Kg ha^{-1}): Among the sowing methods, (M_2) Line sowing recorded significantly higher nitrogen content in grain (1.92%) and straw (0.42%). This result was markedly superior compared to the other treatments. However, significantly higher nitrogen uptake by grain (45.12 Kg ha^{-1}), straw (15.17 Kg ha^{-1}) and total uptake (60.29 Kg ha^{-1}) were recorded with (M_3) Criss-cross sowing method which was statistically at par with (M_2) Line sowing.

In case of fertility levels, significantly higher nitrogen content in grain (1.90%), straw (1.64) and nitrogen uptake by grain (51.60 Kg ha^{-1}), straw (18.73 Kg ha^{-1}) and total uptake (70.34 Kg ha^{-1}) were recorded under application of (N_2) 125% RDF. But nitrogen uptake in straw was statistically at par with application of (N_3) 100% RDF.

Phosphorus content (%) and their uptake (Kg ha^{-1}): Among the sowing methods, (M_2) Line sowing recorded significantly higher phosphorus content in grain (0.426%) and straw (0.185%) which was statistically at par with (M_3) Criss-cross method of sowing. This result was markedly superior compared to the other treatments. However, significantly higher phosphorus uptake by grain (10.76 Kg ha^{-1}), straw (7.12 Kg ha^{-1}) and total uptake (17.71 Kg ha^{-1}) was recorded with (M_3) Criss-cross sowing method which was statistically at par with (M_2) Line sowing except total uptake of phosphorus.

In case of the fertility levels, significantly higher phosphorus content in grain (0.464%), straw (0.241%) and phosphorus uptake by grain (12.68 Kg ha^{-1}) was recorded under the application of (N_2) 125% RDF which was statistically at par with application of (N_3) 100% RDF. However, straw (9.78 Kg ha^{-1}) and total (22.46 Kg ha^{1}) uptake were also higher under application of (N_2) 125% RDF.

Potassium content (%) and their uptake (Kg ha^{-1}): Sowing methods of (M_2) Line sowing achieved significantly higher potassium content in grain (0.49%) and straw (1.27%) which was statistically at par with (M_3) Criss-cross method of sowing. However, significantly higher potassium uptake by grain (11.95 Kg ha^{-1}), straw (52.84 Kg ha^{-1}) and total uptake (64.79 Kg ha^{-1}) were recorded with (M_3) Criss-cross sowing but uptake by grain was statistically at par with (M_2) Line sowing.

In case of fertility levels, significantly higher potassium content in grain (0.49%), straw (1.36%) and potassium uptake by grain (13.05 Kg ha^{-1}) was recorded under application of (N_2) 125% RDF which was statistically at par with application of (N_3) 100% RDF. However, significantly higher potassium uptake by straw (55.70 Kg ha^{-1}) and total uptake (68.75 Kg ha^{-1}) were recorded under application of (N_2) 125% RDF.

This may be due to that suitable sowing method helped in seed placement at proper depth and uniform seed distribution, creating better seed to soil contact, faster plant emergence and more homogenous plant stand. The production of biomass and the concentration of nitrogen, phosphorus and potassium affect the uptake of nutrients. In the current study, criss-cross sowing enhanced dry matter production, grain, straw and biological yield leading to increased intake of nitrogen, phosphorus and potassium. According to Hada *et al.* (2013) [13], criss-cross sowing method improved nutrient utilization, resulting in increased yield and eventually higher nutrient uptake by the crop. Similar finding were also reported by Singh *et al.* (2015) [30]. Among the fertility level significantly higher NPK content and uptake was recorded with the application of 125% RDF. This might be due to higher grain and straw yield under the application of 125% RDF. Same results were also found by Trivedi *et al.* (2020) [31].

Available NPK (Kg ha^{-1}): Among the sowing methods significantly higher availability of N (340.60 Kg ha^{-1}), P (56.53 Kg ha^{-1}) and K (237.52 Kg ha^{-1}) after harvest were recorded under (M_1) Broadcasting method of sowing.

In case of fertility levels, significantly higher availability of nitrogen and phosphorus (372.41 and 76.10 Kg ha^{-1}, respectively) was recorded with application of (N_2) 125% RDF. However, potassium availability was found to be non-significant. It can be inferred that available NPK was depleted significantly by the crop sown with criss-cross methods when compared to their initial NPK status. Proper sowing method encourage nutrient availability, proper light penetration for photosynthesis, good soil environment for soil nutrient uptake and water use efficiency which enhances crop vigor and yield. Similar findings were also observed by Pandey and Kumar (2005) [22]; Abbas *et al.* (2009) [1]; Singh and Chaturvedi (2023) [28]. Significantly higher availability of nitrogen was recorded with the application of 125% RDF. This might be due to higher application of NPK then any other treatments. Same results were also noticed by Jat *et al.* (2013) [14]; Rakshit *et al.* (2015) [24]; Trivedi *et al.* (2020) [32].

Table 1: Yield (Kg ha^{-1}) and harvest index (%) 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 2: Nitrogen content (%) and their uptake (Kg ha^{-1}) by wheat as influenced by different fertility levels and sowing methods at harvest

Treatments	Nitrogen content (%)		Nitrogen uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
Main plot (Sowing methods)					
M_1: Broadcasting	1.68	0.38	31.00	11.23	42.15
M_2: Line sowing	1.92	0.42	43.79	14.76	58.55
M_3: Criss cross	1.73	0.38	45.12	15.17	60.29
SEm±	0.05	0.01	1.09	0.39	1.39
LSD (p=0.05)	0.18	0.03	4.26	1.54	5.46
Sub plots (Fertility levels)					
N_1: 0 (control)	1.64	0.29	22.37	6.05	28.31
N_2: 125% RDF	1.90	0.46	51.60	18.73	70.34
N_3: 100% RDF	1.83	0.45	47.10	17.62	64.72
N_4: 75% RDF	1.74	0.37	38.81	12.47	51.28
SEm±	0.04	0.01	1.06	0.38	1.30
LSD (p=0.05)	0.12	0.02	3.16	1.14	3.87
Interaction (M*N)	NS	NS	NS	NS	NS

Table 3: Phosphorus content (%) and their uptake (Kg ha^{-1}) by wheat as influenced by different fertility levels and sowing methods at harvest

Treatments	Phosphorus content (%)		Phosphorus uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
Main plot (Sowing methods)					
M_1: Broadcasting	0.359	0.161	6.93	5.10	12.03
M_2: Line sowing	0.426	0.185	10.01	6.87	16.88
M_3: Criss cross	0.396	0.171	10.76	7.12	17.71
SEm±	0.008	0.004	0.32	0.24	0.56
LSD (p=0.05)	0.032	0.017	1.25	0.93	2.19
Sub plots (Fertility levels)					
N_1: 0 (control)	0.280	0.058	3.89	1.23	5.11
N_2: 125% RDF	0.464	0.241	12.68	9.78	22.46
N_3: 100% RDF	0.445	0.232	11.78	9.03	20.58
N_4: 75% RDF	0.383	0.159	8.58	5.42	14.00
SEm±	0.007	0.003	0.31	0.23	0.54
LSD (p=0.05)	0.020	0.010	0.93	0.68	1.62
Interaction (M*N)	NS	NS	NS	NS	NS

Table 4: Potassium content (%) and their uptake (Kg ha^{-1}) by wheat as influenced by different fertility levels and sowing methods at harvest

Treatments	Potassium content (%)		Potassium uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
Main plot (Sowing methods)					
M_1: Broadcasting	0.42	1.16	7.82	33.64	41.46
M_2: Line sowing	0.49	1.27	11.26	43.75	55.01
M_3: Criss cross	0.46	1.38	11.95	52.84	64.79
SEm±	0.01	0.04	0.35	1.59	1.77
LSD (p=0.05)	0.04	0.14	1.36	6.25	6.96
Sub plots (Fertility levels)					
N_1: 0 (control)	0.41	1.16	5.73	24.55	30.28
N_2: 125% RDF	0.49	1.36	13.05	55.70	68.75
N_3: 100% RDF	0.48	1.30	12.37	50.50	62.87
N_4: 75% RDF	0.45	1.25	10.22	42.89	53.11
SEm±	0.01	0.02	0.30	1.58	1.76
LSD (p=0.05)	0.02	0.07	0.88	4.68	5.22
Interaction (M*N)	NS	NS	NS	NS	NS

Table 5: Nutrient availability (Kg ha^{-1}) in soil after harvesting of wheat as influenced by sowing methods and fertility levels

Treatments	Available N (Kg ha^{-1})	Available P (Kg ha^{-1})	Available K (Kg ha^{-1})
Main plot (Sowing methods)			
M_1: Broadcasting	340.60	56.53	237.52
M_2: Line sowing	324.20	51.68	223.47
M_3: Criss cross	322.46	50.85	214.19
SEm±	1.39	0.56	1.77
LSD (p=0.05)	5.46	2.19	6.96
Sub plots (Fertility levels)			
N_1: 0 (control)	264.44	18.45	226.20
N_2: 125% RDF	372.41	76.10	225.23
N_3: 100% RDF	348.03	62.98	223.61
N_4: 75% RDF	331.47	54.56	225.87
SEm±	1.30	0.54	1.76
LSD (p=0.05)	3.87	1.62	6.16
Interaction (M*N)	NS	NS	NS
Initial value	292.75	26.56	256.48

Conclusion

Results indicated that among the sowing methods, significantly higher NPK content was recorded under Line sowing method which was statistically at par with Criss-cross method. However, significantly higher yield and NPK uptake was recorded under Criss-cross method which was statistically at par with Line sowing method. In case of fertility levels, significantly higher yield, NPK content and NPK uptake was recorded with application of 125% RDF which was statistically at par with application of 100% RDF under mid-hills of Himachal Pradesh.

References

1. Abbas G, Ali MA, Abbas G, Azam M, Hussain M. Impact of planting methods on wheat grain yield and yield contributing parameters. J Anim Plant Sci. 2009;19(1):30-33.
2. Abd El-Lattief EA. Bread wheat (*Triticum aestivum* L.) productivity and profitability as affected by method of sowing and seeding rate under Qena environment. Asian J Crop Sci. 2014;3:188-196.
3. Akhter MM, Hossain A, Timsina J, Teixeira da Silva JA, Islam MS. Chlorophyll meter-A decision-making tool for nitrogen application in wheat under light soils. Int J Plant Prod. 2016;10(3):289-302.
4. Ali N, Durrani S, Adeel Shabaz M, Hafeez A, Ameer H, Ishfaq M, *et al*. Effect of different nitrogen levels on growth, yield and yield contributing attributes of wheat. Int J Sci Eng Res. 2018;9(9):595-602.
5. Anwar S. Nitrogen and phosphorus fertilization of improved varieties for enhancing yield and yield components of wheat. Pure Appl Biol. 2016;5(4):727-737.
6. Barnes A, Greenwood DJ, Cleaver TJ. A dynamic model for the effects of potassium and nitrogen fertilizers on the growth and nutrient uptake of crops. J Agric Sci. 1976;86(2):225-244.
7. Bhaskar GP, Shrivastava GK, Sumit. Effect of sowing methods, seed rates and nutrient management on productivity and profitability of wheat (*Triticum aestivum* L.) in northern-hill zone of Chhattisgarh. Pharma Innov. J. 2022;11(11):301-307.
8. Biljana B, Aca M. Correlation between nitrogen and chlorophyll content in wheat (*Triticum aestivum* L.). Kragujevac J Sci. 2009;31:69-74.
9. Bungard RA, Wingler A, Morton JD, Andrews M, Press MC, Scholes JD, *et al*. Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in *Clematis vitalba*. Plant Cell Environ. 1999;22:859-866.
10. Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant Soil. 2008;1(17):302.
11. Dhakal Y, Meena RS, Kumar S. Effect of INM on nodulation, yield, quality and available nutrient balance in soil after harvest of green gram. Legume Res. 2016;39(4):590-594.
12. Gasser JKR, Thorburn MAP. The growth, composition and nutrient uptake of spring wheat. J Agric. Sci. 1972;78(3):393-404.
13. Hada N, Nepalia V, Tomar SS. Influenced of balanced nutrition, weed control and sowing methods on yield and nutrient uptake by durum wheat (*T. durum* Desf.). Ann Plant Soil Res. 2013;15:19-22.
14. Jat L, Singh SK, Latare AM, Singh RS, Patel CB. Effect of dates of sowing and fertilizer on growth and yield of wheat (*Triticum aestivum*) in an Inceptisol of Varanasi. Indian J Agron. 2013;58(4):611-614.
15. Kenedy E, Maral E. Shoot and root biomass, phosphorus and nitrogen uptake of spring wheat grown in low phosphorus and moisture content conditions in a pot experiment. J Plant Nutr. 2012;41(17):2273-2280.
16. Krentos VD, Orphanos PI. Nitrogen and phosphorus

fertilizers for wheat and barley in a Semi-Arid Region. J Agric Sci. 1979;93(3):711-717.
17. Krezel R, Sobkowicz P. The effect of sowing rates and methods on winter triticale grown on light soil. J Sci. 2013;11(3):69-78.
18. Kumar M, Singh SK, Bohra JS. Cumulative effect of organic and inorganic sources of nutrients on yield, nutrients uptake and economics by rice-wheat cropping system in Indo-Gangetic Plains of India. Commun. Soil Sci. Plant Anal. 2020;51(5):658-674.
19. Lawlor DW, Kontturi M, Young AT. Photosynthesis by flag leaves of wheat in relation to protein, ribulose Awphosphate carboxylase activity and nitrogen supply. J Exp. Bot. 1989;40:43-52.
20. Malik K, Lathwal PO, Dhaka KA, Tamboli AY, Singh A, Kumar P, *et al*. Effect of different sowing methods and varieties on growth and yield performance of wheat crop. J Nat Resour Conserv Manag. 2021;2(1):1.
21. Nasrullah HM, Cheema MS, Akhtar M. Efficacy of different dry sowing methods to enhance wheat yield under cotton-wheat cropping system. Crop Environ. 2010;1:27-30.
22. Pandey IB, Kumar K. Response of wheat (*Triticum aestivum*) to seeding methods and weed management. Indian J Agron. 2005;50:48-51.
23. Prasad R. Fertilizer and manures. Curr Sci. 2012;102(6):894-898.
24. Rakshit R, Patra AK, Purakayastha TJ, Singh RD, Pathak H, Dhar S, *et al*. Effect of super-optimal dose of NPK fertilizers on nutrient harvest index, uptake and soil fertility levels in wheat crop under maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system. Int. J Bioresour. Stress Manag. 2015;6(1):15-23.
25. Ralph RL, Ridgman WJ. A study of the effects of potassium fertilizer with special reference to wheat on boulder-clay soils. J Agric Sci. 1981;97(2):261-296.
26. Singh A, Yadav DD, Balaji R, Kallam PR, Bhatt M, Dawadee P, *et al*. Studies on effect of methods of sowing and integrated nutrient management in late sown wheat (*Triticum aestivum* L.). Int. J Curr. Microbiol. Appl. Sci. 2018;7(5):3199-3205.
27. Singh KR, Dixit A, Shukla KR, Thakur M. Effect of sowing methods and weed management on growth yield attributes and yield of wheat in Chhattisgarh plains. Int J Chem Stud. 2020;8(3):2102-2106.
28. Singh M, Chaturvedi PK. Sowing methods and nitrogen levels effect on growth, yield and economics of wheat (*Triticum aestivum* L.). Pharma Innov. J. 2023;12(1):1030-1032.
29. Singh S, Malik RK, Rajbir G, Devraj, Sheoran P. On-farm nitrogen use pattern in wheat in the rice-wheat cropping system of the Trans-Gangetic Plains of India. Cereal Res Commun. 2012;40:122-134.
30. Singh, Pandey MB, Tuti DM, Singh S, Bisht KJ. Performance of rainfed wheat under different fertility levels and sowing methods in the mid hills of north-western Himalayas. Res. Crops. 2015;16(1):37-41.
31. Tariq JMT, Arif M, Akbar H, Ali S. Response of wheat to source, type and time of nitrogen application. Sarhad J Agric. 2007;23:871-879.
32. Trivedi VK, Raza MDB, Dimree S, Verma AK, Pawar AB, Upadhyay DP, *et al*. Effect of balanced use of nutrients on yield attributes, yield and protein content of wheat (*Triticum aestivum*). Indian J Agric Sci. 2020;90(12):2369-2372.
33. Uthayakumaran S, Wrigley C. Wheat: Characteristics and quality requirements. In: Cereal grains. Amsterdam: Elsevier; c2010. p. 59-111.