INFLUENCEOFSOWINGPATTERN AND SEED RATEON PLANTGROWTH ANDYIELDINWHEAT(*Triticum aestivum*)

ABSTRACT

The majority of people on earth consume wheat (*Triticum aestivum*) as a staple grain. It is themost important crop of Himachal Pradesh during winter season in low and mid hills of the State.Inordertoensureoptimumplantdispersionoverthe cultivatedareaandbetterutilizebothabove-andbelow-groundnaturalresourcesinordertoincreaseyield,manipulationofagronomicpracticessuch planting pattern/geometry and seed rate is thought to be the first step. Both in-field andlaboratory-based investigation was undertaken to study the impact of different planting patternsand seed rates on seed production in wheat by evaluating the yield parameters. The experimentwith twelve treatment combinations comprising of four planting patterns (15 cm, 23 cm, 15 x 15cm and 23 x 23 cm) and three seed rates (100, 120 and 140 kg/ha) was conducted in RandomizedBlock Design with three replications at the experimental farm of department of Seed Science andTechnology. The observations showed that compared to other planting patterns, 23 x 23 cmplanting patterns significantly increased plant height, leaf area index, number of spikes/m^2, spikelength,numberofspikeletsperspike,numberofgrainsperspike,biologicalyield,seedyield,andseedrecoverypercentage.Thenumberofshoots/m^{2}afterfullemergence,daysto50%heading,orharvest index did not significantly differ with planting pattern. 140 kg/ha seed rate producedsignificantly higher number of shoots per m², leaf area index, number of spikes per m², biologicalandseed yield over 120 kg/haand 100 kg/haseed rate.

Keywords: Plantingpattern,Yield,Wheat, leafarea index,harvest index

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Abbreviations: %: Per cent; @: At the rate; °C: Degree Celsius; CD: Critical Difference; cm: Centimetre; et al.: et alii (and other); g: Gram; g/ha: Gram per hectare; g/m^2: Gram per square metre; ha: Hectare; K: Potassium; kg: Kilogramme; kg/ha:Kilogramme per hectare; m ha: Million hectare; m^{-2}:Per square metre; mm:Millimetre; m t: Million tonnes; N: Nitrogen; No.: Number; /: per; P: Phosphorus; pH: Power of hydrogen ions; q/ha: Quintal per hectare; t/ha: Tonne per hectare.

INTRODUCTION

Wheat(*Triticumaestivum*)isthemostimportantcropforthemajorityofworld'spopulation.Itistheimportantstaplefoodofabouttwobillionpeople(36%oftheworldpopulation). It is the source of flour for the world's breadmaking. Much of the wheat used forlivestock and poultry feed is a byproduct of the flour milling industry. Wheat straw is used forlivestockfeeding.Wheatisanutrient-densefoodthatishighincarbohydratesaswellasimportantproteins, minerals, and vitamins. Industrial uses of wheat grain include starch for paste, alcohol,oil,and gluten.

World production of wheat is 749 million tonnes, making it the second most importantcereal. India is the second largest producer of wheat after China. Wheat originated in

SoutheastAsia. In India three species of *Triticum* mainly *aestivum*, *durum* and *dicoccum* are cultivated andoccupyapproximately95,4and1percentarea,respectively.*Triticumaestivum*iscultivatedinalltheregionsofthecountrywhile*durum*iscultivatedinPunjabandCentralIndia,and*dicoccum* inKarnataka only. In India, wheat occupies an area of 31.61 m ha with a production of 109.52 m tandaverageyieldof 34.64 q/ha(Anonymous2021).

Lowtilleringduetoprolongedlowtemperatureatinitialstagesresultsinsub-optimalplantpopulationandimproperutilizationofnaturalresourcesandotherinputs.Lightmodifiesthe entiremicro-environment within the crop canopy. Planting pattern too modifies the crop environment(Kler and Bains 1992). Increasing the plant densities by higher seed rates had been visualized asone of the best ways to increase the yield. Appropriate planting arrangement with suitable plantpopulation is vital for efficient use of available resources like solar radiation, soil moisture andbetter weed management. Uniform distribution of plants over cropped area and bidirectionalorientation of plants to harvest maximum radiation through its greater penetration in crop canopyresults in higher productivity.

Manipulation of agronomic practices such as planting pattern/geometry and seed rate areconsidered to be foremost steps to achieve proper distribution of plants over cultivated area,thereby better utilization of above and below ground natural resources towards increasing seedyield.

MaterialsandMethods

TheexperimentwasconductedatExperimentalFarmofDepartmentofSeedScienceandTechnology,CollegeofAgriculture,ChaudharySarwanKumarHimachalPradeshKrishiVishvavidyalaya, Palampur during *Rabi* 2015-16. The experimental farm is situated at 32 6’ Nlatitude,763’Elongitudesatanelevationof1290.80m(a.m.s.l).ItfallsinthemidhillzoneoftheShivalik ranges of Himachal Pradesh. The climate of the region is characterized as wet temperatewithmildsummers(MarchtoJune)andcoolwinters.Thesoilofexperimentalsitewassiltyloamintexture,slightlyacidicinnatureandclassifiedas *TypicHapludalf*aspertheTaxonomicSystemofSoilClassification.Therewas10.3meg/100gsoilCEC,0.59%O.C.,356.1kg/haavailable~~N(~~N (SubbiahandAsija,1956),15.6kg/haavailableP(Olsenetal.,1954)and184.7kg/haavailableK(Merinand Peech,1950).

An experiment with twelve treatment combinations comprising of four planting patterns (15 cmrow to row, 23 cm row to row, 15 x 15 cm criss cross and 23 x 23 cm criss cross) and three seedrates(100,120and140kg/ha)wasconductedinRandomizedBlockDesignwithfourreplications.

Wheat variety HPW 236 was sown by hand as per planting pattern. Seeds were dropped behindthe plough in the furrow with the help of manual labour by hand. Recommended dose of nitrogen@ 120 kg/ha was applied in two equal splits through urea (46% N) half at sowing and theremaining half was top dressed at the time of first irrigation after 40 days of sowing at CRI stagebybroadcastmethod.Auniformbasaldoseof60kgP_2O_5and40kgK_2Operhectarewereappliedthrough SSP and MOP, respectively at the time of sowing, by band placement in the furrow.Isoproturon and 2,4-D were used for weed control after 40 days of sowing. Combination ofisoproturon and 2,4-D @ 1.0 and 0.5 kg/ha respectively was used for the control of mixedpopulation of weeds. Harvesting was done manually with sickles and crop produce was threshedwiththehelp of aplotthresher.

Resultand Discussion

Effect of sowing pattern and seed rate on growth attributesNumberofshoots/m^{2}aftercompleteemergence

The number of shoots was not influenced significantly by the sowing pattern. The outcomes were in contrast to those of Jat and Singhi (2004) and Pandey and Kumar (2005), who found that different sowing pattern affected the number of shoots per square metre.

However, higherseedrateresultedinproductionofsignificantlymore numberofshoots(145.0)perunitarea.Thiswasduetomorenumberofseedsownperunitofarea. Similar outcomes were also observed by Rosy (2003).

PlantHeight

Therewasnosignificantdifferenceinplantheightduringinitialstages*i.e.*,at30to60DAS.Plantheight was significantly affected after 90 days of sowing. Significantly more plant height wasrecorded in cross sowing at 23 cm as compare to all other treatments. The similar trend wasobservedduringdifferentstagesofcropgrowthtillharvest.ItcouldbeduetomoreLAIafter90

daysofsowingwhichresultedinthevigorousgrowthofplantsduetobettersunlight,aerationandother micro environmental conditions as compared to other treatments. Sowing at 23 cm

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Formatted: Indent: First line: 0.59", Right: 0.15", Space Before: 0 pt rowspacingwasatparwith15x15cmcrosssowingandproducedsignificantlytallerplantscomparedto narrow row spacing of 15 cm. Similar results were obtained by Tigabu and Asfaw (2016) who discovered that the height of plants was significantly affected by the different row spacings.

There was no significant increase in plant height with increase in seed rate up to 140 kg/ha at all the stages of crop growth. Different seed rates in wheat had little to no impact on plant height, according to Rosy (2003).

50percentheadingstage

The perusal of data revealed that 50 percent heading was not significantly influenced by differentsowingpatternsandseedrates.Thismaybeduetofavourableclimateforfloweringataparticularp ointof time. According to Kalpana et al. (2014) studies, the alternation of row arrangement had no appreciable impact on days to 50% heading.

Leafareaindex

Consistent and significant increase in LAI was recorded in the order of 15 cm, 23 cm, 15 x 15 cmand 23 x 23 cm sowing patterns. Similarly, increase in seed rate from 100 to 140 kg/ha caused asignificant increase in LAI. This could be due to better environmental conditions of plants byproperdistributionofplantsresultingin increasedinterception,absorption,andutilizationofphotosynthe ticallyactiveradiation(PAR),therebyresultinginhigherphotosynthesisandfinallyhigherLAI in cross sowing. This could also be due to proper utilization of nutrients, water, air andsunlight in cross sowing and closer sowing. According to Pandey and Kumar (2005), criss-cross sowing (20 cm x 20 cm) reported a significantly higher leaf area index than broadcasting and line sowing.

Higher LAI with increase in seed rate may be due to more number of plants per unit area ultimately increased light interception and net assimilation rate depending on specific plant. Bavec et al. (2007) also reported similar results when increased seed rates from 350 to 800 viable seeds m^2.

Numberof Spike/m^2

Thenumberofspikeswassignificantlyinfluencedbysowingpattern.Crosssowingat23x23cmproduceds ignificantlyhighestnumberofspikesperunitareaascomparedtoallothermethodsofsowing. Normal sowing at 23 cm row spacing also produced significantly more number of spikesthan closer sowing at 15 cm. An improvement in number of spikes under cross sowing could beon account of vigorous growth and higher tillering of plants due to more uniform distribution of sowing.Kumpawat(1998), Hussianetal.(2003) and Mekonnen (2020) reportedsimilarresults.

Thenumberofspikeswassignificantlyinfluencedbythedifferentseedrates.Thenumberofspikesincreasedsignificantlywithincreaseintheseedrate.This may be because of more number of mother shoots because of higher seed rates in result more plants being established. This study is in line with the findings of Worku (2008) who reported that the number of productive spikes per 0.5 m row length increased linearly with increasing rates of seeding from 72.31 spikes per 0.5 m row length at the seeding rate of 100 kg ha-1 (the lowest rate) to 85.95 spikes per 0.5 m row length at the highest (150 kg ha-1) seeding rate. Kalita and Choudhary (1984), Sarkar and Torofder (1992), Ahmed et al. (1995), Kumpawat (1998), Rosy (2003) and Mekonnen (2020) all reported comparable findings for wheat.

Spikelength (cm)

Significantlymorespikelengthwasrecordedincrosssowingat(23x23cm)comparedtoallothersowing patterns followed by (15 x 15 cm) spacing. It could be on account of vigorous growth ofplants due to more uniform distribution of plants per unit area which resulted in proper utilizationof nutrients, water, air and sunlight in cross sowing. Normal sowing of 23 cm and closer sowingat 15 cm row spacing produced more or less similar spikes and remained at par with each other.Prasadetal.(1991),KlerandBains(1992),PariharandSingh(1995),SharmaandAngrias(1996),Kumpawat (1998) and Pandey and Kumar (2005) and reported similar results.

Seed rate did notaffect the spike length significantly. Singh and Singh (1984), Sarkar and Torofder (1992), Singhetal. (1995)and Pandeyetal.(1999) reported similarresultsinwheat.

Numberofspikelets perspike

Significantlymorespikeletsperspikewererecordedincrosssowingat(23x23cm)comparedtoall other sowing patterns followed by (15 x 15 cm) spacing. This was due to more spike length.Normal sowing of 23 cm and closer sowing at 15 cm row spacing produced more or less similarnumber of spikelets per spikes and remained at par with each other. Sharma and Angrias (1996),Sharma and Malik (1993), Jat and Singhi (2004) and Terfa (2020) reported similar results.

Different seed ratesdid not affect the number of spikelets per spike significantly. Singh and Singh (1984) and Pandey etal. (1999) reported similar resultsinwheat.

Table: 1Effectofsowingpattern (cm)andseed rate(kg/ha)on plantheight

Treatments	Plantheight(cm)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
Sowingpattern(cm)						
15	5.9	14.8	31.5	85.9	119.0	119.1
23	6.2	15.0	32.6	88.0	121.9	122.2
15 x 15	6.1	14.9	32.7	88.4	122.0	122.6
23 x 23	6.3	15.2	33.3	90.4	125.3	125.5
SE ±	0.09	0.15	0.23	0.78	0.98	0.99
CDat 5 %	**NS**	**NS**	0.66	2.24	2.81	2.83
Seedrate(kg/ha)						
100	6.1	14.9	32.2	87.0	121.6	121.6
120	6.1	15.0	32.6	88.6	122.2	122.2
140	6.1	15.0	32.8	88.9	122.5	123.3
SE±	0.08	0.13	0.20	0.68	0.85	0.83
CDat 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table: 2 Effect of sowing pattern (cm) and seed rate (kg/ha) on various plant growth and yield attributes

Treatments	Number of shoots/m^2 after complete emergence	50 percent heading stage	Leaf area index	Spike/ m^2	Spike length (cm)	Number of spikelets per spike	Number of grains per spike	Biological yield (q/ha)	Raw seed yield (q/ha)	Graded seed yield (q/ha)	Seed recovery (%)	Harvest index
Sowing pattern (cm)												
15	131.8	124.7	4.3	102.5	10.3	19.1	57.1	96.7	29.2	23.3	79.6	0.30
23	131.3	124.3	4.6	105.5	10.4	19.1	57.6	99.8	30.8	25.6	83.2	0.31
15 x 15	132.8	124.3	4.9	109.5	10.7	19.5	58.3	104.7	31.6	26.7	84.7	0.30
23 x 23	133.5	125.6	5.3	113.2	11.1	20.0	61.0	107.7	32.3	28.4	87.7	0.30
SEm±	0.81	0.51	0.08	0.95	0.10	0.10	0.22	0.44	0.15	0.12	0.43	0.00
CD at 5%	**NS**	**NS**	0.22	2.73	0.28	0.28	0.64	1.27	0.42	0.35	1.22	**NS**
Seed rate (kg/ha)												
100	119.1	124.7	4.5	103.3	10.6	19.3	58.2	100.0	29.8	25.0	83.8	0.30
120	132.9	124.8	4.8	107.3	10.7	19.4	58.4	102.5	30.9	25.9	83.9	0.30
140	145.0	124.6	5.1	112.5	10.7	19.6	58.6	104.1	32.3	27.1	83.8	0.31
SEm±	0.71	0.44	0.07	0.83	0.09	0.09	0.19	0.38	0.13	0.11	0.37	0.00
CD at 5%	2.02	**NS**	0.19	2.36	**NS**	**NS**	**NS**	1.10	0.37	0.31	**NS**	**NS**

EffectofsowingpatternandseedrateonyieldattributesNum

berof grainsperspike

Significantly more number of grains per spike was recorded in cross sowing at (23 x 23 cm)compared to all other sowing patterns followed by (15 x 15 cm) spacing. This was due to morespike length and spikelets per spike. Normal sowing of 23 cm and closer sowing at 15 cm rowspacing remained at par with each other. Kler and Bains (1992), Sharma and Malik (1993), Kumpawat (1998), Jat and Singhi (2004), Pandey and Kumar (2005) and Bakh et al. (2007) reported similar results.

Different seed rates did not affect the number of grains per spike significantly. Sarkar and Torofder (1992) and Pandey et al. (1999) reported similar results.

Biologicalyield(q/ha)

Cross sowing (23 x 23 cm) gave significantly higher biological yield over other sowing patterns.Similarly, Cross-sowing (15 x 15 cm) gave significantly higher biological yield than the linesowing. An improvement in biological yield under cross-sowing appears to be due to vigorousgrowth of the plants which resulted in higher biomass production due to better plant height andLAI. Normal sowing at 23 cm produced significantly more biological yield than closer sowing at15 cm. Kler (1988), Kaur et al. (2001a) and Hussian et al. (2003) reported similar results.

Thebiological yield increased significantly with successive increase in the seed rate from 100 to 140kg/ha. This could be because of higher plant population with increase in seed rate. Khan et al.(2000),Rosy (2003)and Tigabu andAsfaw(2016)reported similar results.

Rawseedyield(q/ha)

Significantly higher seed yield was recorded from cross sowing (23 x 23 cm) over sowing with(15 x 15 cm). Cross sowing gave significantly higher raw seed yield as compare to line sowing.Normalsowingat23cmproducedsignificantlymorerawseedyieldthanclosersowingat15cm.The reason for this increase in seed yield was due to more number of shoots per unit area, morenumber of spikes, more number of spikelets per spike and more number of grains per spike. Kler(1988),Jainetal.(1989),Prasadetal.(1991),KlerandBains(1992),JadhoandNalamwar(1993),SharmaandMalik(1993),Singhetal.(1993),AngirasandSharma(1996),Kauretal.(2001)a, Kauretal.(2001)b,JatandSinghi(2004),Bakhetal.(2007), PandeyandDwivedi(2007) and Terfa (2020)alsoreportedsimilar results.

The raw seed yield increased significantly with increase in the seed rate up to 140 kg/ha.Thiscouldbebecauseofhigherplantpopulationwithincreaseinseedrate.KalitaandChoudhary(1984), Singh et al. (1985), Samra and Dhillon (1987), Kumpawat (1988), Pawar et al. (1988),Khareetal.(1989),Mahajanetal.(1991),Naiketal.(1991),SarkarandTorofder(1992),SharmaandMalik(1993),Singhetal.(1993),Behera(1995),PariharandSingh(1995),Khanetal.(2000)Baloch et al. (2010), Hussain et al.(2010), Worku (2008) and Terfa (2020)also reported similar results. However, Bhargava and Shekhawat (1981)inwheatreported thatdifferentseedrateshadno significanteffectonseedyield.

Gradedseedyield(q/ha)

Trendforgradedseedyieldwassimilarasreportedforrawseedyield.Crosssowing(23x23cm)method gave significantly higher grain yield over cross sowing at (15 x 15 cm), normal sowing at23cmandclosersowingat15cmrowspacing.Differencesamongthelattertreatmentswerealsosignificant and yield decreased in the same order. Cross sowing (23 x 23 cm) planting pattern isshowing10.94%increaseingradedseedyieldovernormalsowingat23cm,6.37%increasewithcross sowing at (15 x15 cm) and 21.89% increase over closer spacing at 15 cm. Cross sowing at(15x15cm)isshowing4.3%increaseingradedseedyieldovernormalsowingat23cmand 14.59%increaseovercloserspacingat15cm.However,closerspacingat15cmisshowing8.98%decreasein graded seedyield over normalsowingat23 cm.

The seed yield increased significantly with increase in the seed rate up to 140 kg/ha. It wasbecause of higher raw seed yield obtained under respective treatment.140 kg/ha seed rate isshowing8.4%increaseingradedseedyieldover100kg/haand4.63%increaseinyieldover120kg/ha.Seedrateof120 kg/haisshowing3.6% increasein gradedyield over100kg/ha.

Seedrecovery(%)

Itisevidentfromthegiventablethatsowingpatterneffectedseedrecoverypercentagesignificantly.Higherseedrecoverypercentagewasrecordedwithcrosssowing(23x23cm)overcross sowing at (15 x15 cm), normal sowing at 23 cm and sowing at 15 cm row spacing becauseof bold seeds obtained due to better input and available resources utilization. The recovery wassignificantly lowest at 15 cm normal sowing while difference due to 23 cm normal and crosssowing at (23 x 23 cm) was not significant. No significant difference was observed in seedrecoverypercentageduetoincreaseinseed rates.

Harvestindex

Perusalofdatarevealedthatdifferentsowingpatternandseedrateshadnosignificanteffectonharvestindex of wheat. Laland Bhardwaj(1982) reportedsimilar results.

Table:3Interactioneffectofsowingpattern and seedrateon gradedseed yield(q/ha)

	Seedrate(kg/ha)		
Sowingpattern(cm)	**100**	**120**	**140**
15	22.65	23.40	23.70
23	25.33	25.55	26.03
15 x 15	25.38	27.18	27.68
23 x 23	26.60	27.5	31.05
SE±CD	0.21		
5%	0.61		

Interactioneffect

Theinteractioneffectofsowingpatternandseedrateongradedseedyieldwassignificant.Comparisonofseedyielddue todifferentseedratesateachofthesowingpatternrecordedthatatcloser sowing of wheat at 15 cm row spacing or cross sowing (15 x 15 cm) difference betweenseedyieldat120and140kg/hawasnotsignificantbutitwassignificantlyhigherover100kg/ha. Whereas in normal sowing of wheat at 23 cm, seed yield was significantly higher at 140 kg/haover the lower seed rates of 100 and 120 kg/ha, the difference between the latter being nonsignificant.Incrosssowingat23x23cm,seedyieldincreasedconsistentlyandsignificantlywithincreasing seed rate from 100 to 140 kg/ha. Comparison of sowing pattern at each seed rateexhibited interesting results. At lower seed rate of 100 kg/ha, difference in graded seed yield dueto cross sowing at 15 x 15 cm and normal sowing at 23 cm was statistically same, but it wassignificantly highest with cross sowing at 23 x 23 cm and significantly lowest at 15 cm normalsowing. At 120 kg/ha yield trends were similar but difference between the cross sown plots at

15x15cmand23x23cmwasnotsignificant,whileitwassignificantlylowestat15cmnormalrowspacing. Athighestseedrateof140kg/haandaconsistentandsignificantincreaseingradedseedyield was recorded in the order of 15 cm, 23 cm, 15 x 15 cm and 23 x 23 cm sowing pattern.Consequently,significantlyhighestgradedseedyieldwasrecordedwithcrosssowingat23x23

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cmusing140kg/ha.However,differencesduetonormalsowingat23cmrowspacingwith140kg/haand crosssowing at15x 15 cmand 23x 23 cmwasnotsignificant.

Conclusion

From the results it can be concluded that criss cross sowing (23 x 23 cm) with 140 kg per hectare is the best combination for quality seed production of wheat.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

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