EFFECT OF CROP ESTABLISHMENT METHODS AND SOWING SCHEDULE ON GROWTH AND YIELD OF WHEAT UNDER RICE-WHEAT CROPPING SYSTEM

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

in

AGRONOMY

By

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Supervised By

Dr. Chandra Mohan Mehta

Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2020

CERTIFICATE I

This is certify that the dissertation entitled, **"Effect of crop establishment methods and sowing schedule on growth and yield of wheat under rice-wheat cropping system"** submitted for the degree of Ph.D in the subject of Agronomy of the School of Agriculture, Lovely Professional University Punjab, is a bonafide research work carried out by Mrs. Vandna Chhabra under my supervision and that no part of this Dissertation has been submitted for any other degree.

Major Advisor

CERTIFICATE II

This is to certify that the dissertation entitled, **"Effect of crop establishment methods and sowing schedule on growth and yield of wheat under rice-wheat cropping system"** submitted by Mrs. Vandna Chhabra (Reg. No. 41700111) to the School of Agriculture, Lovely Professional University Punjab in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the subject of Agronomy has been approved after an oral examination on the same.

Major Advisor

External Examiner

Head of the Department

Dean SAG

DECLARATION

I hereby declare that the dissertation entitled, “**Effect of crop establishment methods and sowing schedule on growth and yield of wheat under rice-wheat cropping system**” is an authentic record of my work carried out at Lovely Professional University as requirement of the degree of Ph. D in the discipline of Agronomy under the guidance Dr. Chandra Mohan Mehta and no part of this research work has been submitted for any other degree or diploma.

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ACKNOWLEDGEMENT

The success of this study cannot solely be attributed to efforts of one individual. Generally, there must be unification of efforts to make such an exercise a success. On that note, the following deserve my thanks and feelings of gratitude.

Primary, I wish to express my sincere gratitude to the administrative and teaching staff, lab and field staff of the Faculty of Agriculture, Lovely Professional University (LPU) for the favorable learning environment and cooperation during my stay at University.

I am indebted to my Supervisor ***Dr. Chandra Mohan Mehta****, Associate Professor, Agronomy, for undertaking the task of supervising this work, his willingness, invaluable criticism during the entire course of my investigations, guidance and assistance.*

I owe my debt of sincere gratitude ***Dr. Harmit Singh Thind,*** *Ex-Professor, Soil Science, PAU. I place respect for his initiative, warm affection, caring nature and ready help which help me to overcome several stumbling blocks during the period of investigation and also in writing of this thesis*

I am thankful to esteemed ***Dr. Ramesh Kumar*** *(HOS, School of Agriculture) for his proper guidance and encouragement during the entire course of present studies.*

I would also like to give special thanks to Dr. S.S. Walia, Dr. Abdul Haris, Dr. Dhaliwal, Dr. Gurpreet, Dr. M.P.S Khurana, Mam Angelina and my students Manpreet, Amritpal, Pankaj, Pankush and Jaskaran for great help offered to me.

Diction is not enough to express my heartful gratitude to my beloved father Mr. S.L. Chhabra and my mother Smt. Saroj Rani, whose selfless love, filial affection; and blessings make my path easier. Their blessings have always been the most vital source of inspiration and motivation in my life .My most cordial thanks goes to my husband Sh. Neeraj Kishore and gracious Children (Akshit and Arshit) for their sacrifice, inspiration and constant encouragement. I am grateful to my brother Mr.Naveen Kumar and sister Mrs.Suman and their families whose help in every way inspired me constantly and molded me into the present position.

Place: Phagwara
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ABSTARCT

The present study entitled "Effect of crop establishment methods and sowing schedule on growth and yield of wheat under rice-wheat cropping system" was carried out during *rabi* season of 2018-2019 and 2019-20 at Lovely Professional University, Phagwara. The experiment was laid out in split- split plot design by taking 27 treatments replicated thrice. Main treatments were rice residue management based wheat establishment methods viz. Residue removal (M1), Residue Incorporation (M2) and Residue Burning (M3) and sub plots as different dates of sowing (D1-20th November; D2-5th December; D3-20th December) and sub-sub plots were nitrogen levels (N1-50% RDN;N2-75% RDN; N3-100% RDN). The soil of experimental site was sandy loam in texture with pH 7.2, EC 0.53 dS m-1, OC 0.43%, available N (258.7 kg ha^{-1}), P (14.7 kg ha^{-1}) and K (50.4kg ha^{-1}). Soil samples were collected before sowing wheat crop to analyze microbial biomass carbon and highest microbial biomass was observed for residue incorporation treatment. Maximum plant height, number of tillers per plant, number of spikes per plant, spike length, number of grains per spike, 1000- grain weight, and grain yield was observed under 20thNovember sowing (Timely sowing) and with 100 % RDN. However, maximum number of spikes per plant, spike length and grain yield and harvest index were significantly highest for residue incorporation method of wheat establishment. Highest straw yield and biomass was noticed for residue burning method. Maximum cost of cultivation was in residual removal treatment followed by incorporation and burning, while highest B: C ratio was for residue burning treatment with first date of sowing and 100 % RDN. It can be concluded therefore that if technologies are designed by keeping in view to cut down the cost of cultivation for incorporation of crop residue, it will serve the purpose of getting maximum monetary benefits due to higher grain yield, maintenance of soil fertility by keeping the nutrients in the soil itself and reduction in environmental degradation due to pollution caused by crop residue burning.

Key Words: Dates of sowing, Grain yield, Nitrogen, Residue, Wheat

INTRODUCTION

The beginning of 21st century is manifested by scarcity of resources and environmental degradation. Numerous problems have emanated with the espousal of traditional rice-wheat cropping system since last forty years, thus cautioning the sustainability of this imperative system. Rice-Wheat (R-W) system is over 10 million ha for producing half of the food grains engrossed in India (Ladha *et al.*, 2009; Singh *et al*., 2014). Punjab adopted high yielding varieties and became overriding wheat producing state in the country with higher wheat productivity (Anonymous, 2012). The deceleration in wheat productivity from 1990s witnessing an alarming situation indicated its connection with nutrient deficiencies in soil and soil fatigue in the state (Kiran, 2014).

Wheat a chief cereal crop ranks second in production in India and sown after harvesting of preceding rice crop in predominating Rice-Wheat Cropping (RWC) system in plains of Indo-gangetic region. Rice residue of height almost 20-25 cm is left after harvesting by using combine harvesters in the field for smooth and speeding up sowing of next crop i.e. wheat. Rice straw disposal cause a major challenge for the farmers, although it contains a plenty of nutrients viz. nitrogen (40%), phosphorous (35%), potassium (85%) and 50% of sulphur (Singh *et al*., 2014) along with lignin, cellulose, silica and phenolic compounds (Gina, 2013). Nitrogen Use Efficiency (NUE) for cereals affected by soil temperature, soil moisture, rate of nitrogen application and crop cultivation practices as well as crop species is approximately 33% (Raun and Johnson, 1999; Halvorson *et al.*, 2001). Research to enhance nutrient use efficiency is indispensable for developing sustainable farming to counteract the incessantly increasing climatic, environmental and economic pressure (Mahler *et al*., 1994).

In India, the R-W system contributes approximately 25% of the total crop residues produced. Farmers by and large utilize wheat straw for feeding animals but rice straw is removed or burnt for facilitating establishment of subsequent crops.

Crop residues which were assumed as waste in earlier times, now regarded as vital natural wealth. About 620 million tonnes of crop residues produced, about 50% is burnt in the field and about 24 Mt of rice residue burnt in N-W India, which is recurrent method of residue disposal also caused decreased microbial activity (Singh *et al*., 2014; Singh and Sidhu, 2014; Zhang *et al*., 2014). More than 80% of rice straw is burnt in Punjab during October-November months by the farmers (Singh *et al*., 2010). Punia *et al*., (2008) estimated district-wise burning of crop residues utilizing remote sensing technique in Punjab and it was around 4,315.35 km^2 as on May 2005. Punjab Remote Sensing Centre (PRSC, 2020) observed about 12057 fire events from 21st September to 23rd October, 2020 and it is assumed by doctors that the emission of smoke will aggravate the COVID-19 situation in the region.

Major reasons causing residue burning are harvesting by combines, not having traditional use of crop residues, non-availability of buyers for rice straw and intensive cropping system as revealed by Singh *et al*, 2019. In-situ incorporation of residue in soil can be managed by conventional tillage that is very costly practice. Surface retention and mulching play crucial role in suppression of weeds (Bimbraw, 2019).

Distinctive soil and crop management strategies are being made and raised to overhaul effectiveness and benefit for addressing residue burning that is cause of carbon emissions, intense pollution of environment and organic matter loss from soil. In contrary to that crop residue returning into the soil by some means can conserve the precious resources and sustainable agriculture. Nutrient immobilization, slow decomposition and short term decreased soil fertility associated with residue incorporation cause worries among farmers. Year to year soil changes are too small to explain the potential soil nutrient status. However, these assist for taking decision regarding nutrient needs for the next season (Shiwakoti, 2018).

The impact of residue burning on air quality is worth consideration. Crop residues incorporation is advantageous for recycling nutrients, a crop grown instantly after that suffers from nitrogen deficiency. Moreover, cultivation of field needs time and energy, and the more carbon to nitrogen ratio required to be rectified by application of additional nitrogen during residue incorporation (Mary *et al*., 1996).

There are different choices for disposing off the straw from the field like motorization, water, and extra manure all together for rice straw to rapidly break down in the field. Likewise, the debasement of straw may prompt huge discharge of gases (Bakker *et al*., 2013).

Emission of CO, CH_4, and N_2O (Gupta *et al*., 2004) and estimated emission from open-field during the year 2000 through burning residues of wheat and rice crops in India were 2306 Gg, 110 Gg and 2.3 Gg respectively. Sequestration of organic carbon assists in mitigation of GHGs, enhancing soil fertility while keeping away environmental degradation due to residue burning. Despite announced illegal by the Punjab Government, rice and wheat residues are burnt every year in Punjab. Incessant burning or removal of crop residues may result into nutrients loss, thus higher nutrient cost for shorter run and declining soil quality and productivity in a long run. Sidhu *et al*., (2007) estimated monetary values of major fertilizers (N, P and K) present in paddy straw to the tune of Rs. 424, 96 and 231 per hectare respectively, however tillage required for incorporation of residue may be costlier than straw burning. The use of crop models in agriculture is highly encouraged for sustainable agriculture (Patricia *et al*., 2013).

As crop yields are stagnating and arable lands are shrinking, there has been increasing attention in crop residue management options all over the world for sustaining crop production for the next century. Moreover, optimum date of sowing as well as nitrogen application levels are of much importance along with apposite residue management of rice for increasing productivity of succeeding wheat crop. By keeping in view the gaps existing in this area, research was planned with following objectives:

Objectives:

1. To assess the effect of different crop establishment methods and sowing schedules on growth parameters and yield of wheat crop
2. To evaluate the impact of nitrogen application on available nitrogen and nitrogen use efficiency in wheat
3. To find out the economics of varied temporal regimes and methods of sowing in rice-wheat system
4. To evaluate the field experiment through crop modeling.

Chapter-II

REVIEW OF LITERATURE

Pertinent literature is reviewed pertained to the topic and a brief review of the work done is discussed in the section under the below given headings:

2.1 Rice wheat system (RWS) and emerging challenges

2.2 Impact of management options on sustainable crop production

2.2.1. Impact of wheat establishment methods and sowing schedules on

2.2.1.1 Crop growth and yield

2.2.1.2 Soil health

2.2.1.3 Economics

2.2.2. Crop yield evaluation through crop modeling

2.1 Rice wheat system and emerging challenges

Rice -wheat is the predominant crop production system with about 12.3 million ha area occupied in India and out of this, almost 85 percent lies in Indo-Gangetic plains (Ladha *et al*., 2003) spreading from Punjab to West Bengal. Sustainability of this system has been under threat due to yield stagnation, lowering water table and environmental degradation and climatic variability.

Traditionally rice is cultivated by transplanting method and after harvesting of rice, wheat is established by burning the rice residue in the field and after that preparation of land is done by tillage and planking operations. Establishment of wheat after rice by using conventional methods disturbs the ecosystem of soil by oxidation of organic matter, disintegration of soil aggregates and creating atmospheric pollution. Although enhancement of food grain production is the need of hour for feeding escalating human race, but the methods adopted for rice and wheat establishment are resource intensive and an alarming bell for sustainability of rice-wheat system for long term.

Declining water table has negative effects like increasing cost of cultivation of crops due to irrigation and poor quality of water extracted from deeper layers due to higher salt concentration (Foster *et al*., 2018). Seventy five to eighty five percent fall in groundwater has been observed in North India (Anonymous, 2019). Excessive use of nitrogenous fertilizers is the root cause of polluted groundwater and the problem is shoddier in sandy soils, as in these soils frequent irrigations and extra nitrogen has to be applied to maintain the productivity of the crops. Weed diversity is also the significant hitch faced by rice-wheat cropping system. With changing crop establishment methods, diverse type of weeds affects the crops (Singh *et al*., 2012). It becomes challenging to check the weeds and increase the crop yields in a cropping system, simultaneously by taking care of atmospheric nattiness also.

As rice and wheat crops grows lavishly under appropriate moisture and nitrogen doses, so the field area becomes a hub for insect pest and diseases. Presence of pathogens or insects cause increased cost of cultivation and declining grain yields (Bhatt *et al*., 2016). Degraded soil structure is also a great concern to paddy cultivation under puddled conditions causing soil compaction and increased bulk density. Wheat cultivation after rice on degraded soil may lead to poor development of plant roots. Poor soil health is also due to deficiency of nutrients, low or high pH and water stress.

On farm residue management is the foremost issue in current scenario under RWS. Wheat residue can be used as animal feed, however higher silica content present in paddy straw make it uncongenial to be used for feeding the animals. Moreover, rice straw has wider carbon to nitrogen ratio which make it unfit for incorporation because it may cause immobilization of nitrogen in the soil so wheat yield can decline, if established after residue incorporation of rice (Moritsuka *et al*., 2004). To ensure timely sowing of wheat after paddy harvest, farmers burn their rice stubbles in the field by partial or full burning to get rid of higher cost of removal and incorporation of residue. Moreover, they don’t take interest in residue incorporation, as it leads to lesser grain yield in few initial years.

Traditional practice of rice residue burning destroys the precious natural resources and emits green house gases in the atmosphere.

Heat stress too another issue to be taken care of in Indo-Gangetic plains, as a noteworthy part of India where wheat is cultivated is under terminal heat stress at grain filling time. Climate variability is igniting the fire already broken by increasing maximum and minimum temperature and changing rainfall patterns, affecting the wheat production in the country. Timely sowing of wheat in these circumstances becomes very significant to get higher benefit cost ratio. Wheat establishment can also be done timely by taking short duration variety of rice before wheat or by cultivation of Basmati rice which produces fewer residues.

There are many alternative options to manage the paddy residue in-situ and establish the wheat crop by using Happy Seeder, Straw Cutter and Spreader (SMS), Straw shedder as an attachment to rice harvesters. Happy Seeder can cause farmer responsiveness and impede flaming of left- overs of crop. Alternative uses of rice residue such as paddy compost, energy production, ethanol production, biogas, residue gasification, bio-oil, and biochar production etc. will also discourage the residue burning by farmers.

For getting more sustainable wheat production under rice-wheat cropping (RWC) system, there is a dire need of management options like innovative wheat establishment advocating less environmental degradation owing to residue burning, more conservation of resources through residue retention or incorporation with optimum levels of nitrogen application and timely sowing of wheat (Jat *et al*., 2014) .

2.2 Impact of management options on sustainable crop production

2.2.1. Impact of wheat establishment methods and sowing schedules on

2.2.1.1 Crop growth and yield

Appropriate wheat establishment method after harvesting of rice crop through residue management can change the soil micro-environment in favour of succeeding crop. Many farmers do extra tillage operations after harvesting of rice and burning of its residue, while very few incorporates residue to soil for making land suitable for succeeding crop. Residue burning and number of tillage operations deteriorates the quality of soil and enhance environmental pollution also. In various locations of the world, different residue management strategies are adopted depending upon the next crop's sowing time, resources availability and cost of cultivation, but without considering the environmental hazards. Due to differences in rice residue management practices in various areas, productivity of wheat i.e. the next crop after rice also varies (Stone and Savin, 2000).

In most of the cases, residue incorporation acted as an extra advantage to soil health and crop growth and yield as compared to commonly practiced residue burning. Sidhu and Beri (2005) indicated in-situ incorporation of residue as the best substitute existing to rice residue burning. The results of six years' trials emphasized that by rice residue incorporation from 10- 40 days before sowing of wheat, didn't adversely affect productivity of the following wheat- rice and further denied any lingering effect of paddy residue inclusion in subsequent rice after wheat.

An experiment in Pakistan on maize crop for studying the performance of crop when straw was incorporated at different time intervals before planting wheat in the field was conducted by Dahri *et al*., (2018).

All yield causative traits like plant height, grains per cob and yield were the highest under treatment where sowing of maize was done after 60 days of residue incorporation. Bali *et al*., (1986) and Sharma and Mittra (1992) observed that rice residue inclusion 2-3 weeks prior to wheat sowing decreased its grain yield, however wheat straw incorporation at the same time increased grain yield in rice. Singh *et al*., (1996) revealed considerably increased wheat yield by paddy residue incorporation 21 days before sowing. They further added that 14-29% increased organic carbon in the soil. On the contrary, when the paddy residue was amalgamated instantaneously before sowing the wheat, grain yield was reduced due to arrest of nitrogen which adversely caused nitrogen deficiency. Kavinandan *et al*., (1987) observed increased grain yield of wheat and rice by the incorporation of crop residues. Prasad *et al*., (1999) described improved yield (grain) in rice-wheat and soil productiveness after residue incorporation. With maize residues retention than removal in wheat, increase in the wheat yield was observed (Lao *et al*., 2003; Liu *et al*., 2007; Zhang *et al*., 2009; Zhang *et al*., 2010). Finely chopped and evenly spread straw incorporated in the soil has given better results (Lindqvist, 2015).

An experiment was conducted in China by Ye *et al*., (2019) advocating improved yield in no-tillage with straw mulching for summer maize and plough tillage and straw incorporation for winter season wheat crop. Ali *et al.*, (2019) carried out a research in Pakistan at two different sites on residue management practices. They observed that among various residue management practices, residue incorporation produced significantly better yields of rice and wheat crops. Research conducted by Sharma *et al*., (1985, 1987) showed no adverse effect of residue incorporation on wheat and rice yield. Maskina *et al*., (1988) found increased plant height, tillers count, test weight and wheat grain yield with residue incorporation as compared to burning or removal of residue. Badarinath *et al*., (2006) studied crop management in the IGP and demonstrated improved crop yield by residue incorporation.

By increasing nitrogen than recommended dose for rice and wheat crops produced higher yields, revealed by many workers. Singh *et al*., (2005) suggested application of more N @ 20-40 kg per hectare in the form of urea broadcasted for the initial years after residue incorporation on soils. Afterwards recommended dose of fertilizers may help to realize higher productivity in rice- wheat system. Wheat yield was influenced primarily by nitrogen, though the degree of effect was controlled mainly by weather and residual nitrogen in soil reported by Garrido-Lestache *et al*., (2005).

To evaluate the impact of rice residue on grain and straw yield of wheat , Verma and Pandey (2013) studied rice-wheat cropping system (RWCS) during 2007-2009. They revealed that rice residue management options and the diverse nutrients affected the height of plants and tiller number in plants significantly with maximum by 30% additional NPK than recommended during the years of study. Various growth and total produce causative parameters like effective tillers, spike length, grains per spike and grain yield were registered maximum with the additional 30% NPK dose. These findings were in agreement with Malik (1981), who found increased number of tillers in wheat applied with nitrogen @ 240 kg ha^{-1}.

The beneficial effects of incorporation of residue in the soil on plant length and count of tillers were noticed (Meelu *et al*., 1994. They further added that with rising levels of nutrient there was reduced mortality in tillers, improved photosynthetic source, appropriate food and better cell growth.

Higher yields and profits were recorded (Singh and Singh 1995) with 10t/ha rice straw incorporation+1/2 recommended NPK, almost 21 days before rice planting. Sarkar (1997) observed from 2 years' field trials at Modipuram that with the incorporation of 50% of the crop residues added with recommended NPK every time gave higher rice and wheat yields. Kumar *et al*., (1995) revealed increased yields of grain +straw with every augmentation of nitrogen at Karnal along with higher N uptake. Rajput (1995) observed that incorporation of wheat straw @ 10t/ha led to about 50% savings of fertilizers along with higher yield in rice. The subsequent crops were also benefited considerably.

In R-W cropping system, the application of crop residues + FYM produced more grain yield compared to 100% NPK alone, suggested by Prasad and Sinha (1995). Moreover, Chandra (2017) indicated that rice residue incorporation along with FYM and *Trichoderma* not only improved the yield of successive wheat but also the soil properties at Raipur. However, the peak yield of grain and straw was achieved with 100% crop residue incorporation along with 10 kg Zn/ha in rice wheat crops in R-W cropping pattern as highlighted by Kumari *et al*., (2018) in Bihar. Choudhary (2015) reported enhanced weed management, elevated yield productivity with higher net returns after combining zero tillage, early planting and full residue in wheat crop.

In a study conducted in U.P. (Misra *et al.*, 1996), rice and wheat productivities amplified by integration with straws @ 20 kg additional N ha^{-1} at starting over incorporation without nitrogen and residue burning methods and further supported by Yadav (1997) who observed that where succeeding crops cultivated on the residues of the preceding crops, application of nitrogen @20 kg per hectare was essential at sub-humid climatic condition.

A combination of higher dose of nitrogen with residue incorporation for getting adequate yield in rice was suggested by Pathak and Sarkar (1997). Application of wheat straw with higher nitrogen dose increased rice yield (Kumar *et al*., 2003). However, significant wheat yield increase over recommended fertilizer management practices by incorporation of rice straw was recommended by Varma and Mathur (1990) along with cellulytic microbes and rock phosphate application before sowing wheat. Thakur and Singh (1987) estimated optimum nitrogen rates of 140 kg/ha with wheat straw incorporation and 115 kg/ha without residue for rice.

Results during 1983 to 1991, from field experiments conducted at different locations in India were compiled and it was indicated that recommended NPK and N through wheat straw in the ratio of 50:50 in rice, if followed by full dose of NPK in wheat, stabilized the rice and wheat productivity (Katyal *et al.,* 1998). Thakur and Pandya (1997) reported significantly increased grain yield and N uptake in wheat by mixing urea with rice straw and soil than urea alone. The grain yield acquired by applying 80 kgN/ha+ wheat residue incorporation was significantly higher compared to control (Paikaray *et al*., 2001). They added that the cutback of 40 kg nitrogen per hectare by incorporation of crop residue might be contributed by better nutrient accessibility.

An experiment conducted in Iran, from 2005-2007 by Sadeghi and Bahrani (2009) showed that increasing crop residue rates elevated soil organic carbon and yield attributes. The lowest grain yield was attained might be due to the soil N imbalance by residue incorporation without nitrogen application. The highest crop growth and yield were achieved with application of higher nitrogen doses.

Application of nitrogen in 3 splits significantly produced higher yield and improved nitrogen use efficiency as likened to two equal splits applied during sowing and first irrigation after sowing in their three years study (Singh *et al*., 2010a). The treatments with stubble retention produced higher grain yields than the stubble removal treatments (Huang *et al*., 2012).

Less correlation between residue management and grain yield of Australian wheat, with use of nitrogen up-to 100 Kg/ha was proved to increase wheat grain yield by Bryan *et al*., (2014). Dhar *et al*., (2014) reported superior yield in wheat by application of rice straw and green manure. Singh *et al*., (2014) found that applying nitrogen providing fertilizer higher than recommendation with 15-20 kg/ha at starting and its placement beneath the surface soil produced higher yield in wheat and rice crops as compared to residue incorporation or burning of residue.

Number of spikes, grain count in each spike, test weight (g) and yield (in terms of grain) were appreciably higher when treated with 200 kilo nitrogen in a hectare either straw retained/incorporated than straw burnt was revealed from field investigations (Khalid *et al*., 2014). These results concur with the effects described by Su *et al*., 2014; Karami *et al*., 2012; Wang *et al*., 2014.

From three years' study conducted in Nepal (2015-2017) on rice crop, it was evident that highest grain yield was obtained by incorporation of wheat residue along with 125 kg N applied per hectare (Khatri, 2019). Different opinions were given by many scientists regarding relationship between residue management methods and crop yield. Beri *et al*., (1995) reported decline in yields of rice and wheat by incorporation of residue instantly prior to planting of the next crop as compared to residue removal in a long- term study. In humid tropics, application of crop residues within 4-6 weeks after harvesting might cause quick decomposition and loss of nutrients, so the subsequent crop would not be benefited significantly (Rosenani *et al*., 2003).

From different experiments, it was revealed that with incorporation of wheat and rice residues soil health improved, however no yield increase was reported (Sidhu and Beri, 1989 and Beri *et al*., 1992). Verma and Bhagat (1992) reported that less wheat yield was attained under residue incorporation one month before sowing wheat crop compared to the rice residue burnt or removed. While, studies by Kundu *et al*., (1994) showed that before planting rice, incorporation of wheat straw has slight impact on the following wheat yield.

Release of nitrogen @ 6-9 Kg/ha for varied straw decomposition techniques of rice in wheat crop was observed by Singh *et al*., (2004). They proposed further to such meager amount of N evolved from residue, almost non- significant savings of nitrogen could be expected. Application of rice residue for short term (1-3 year) typically showed a minor effect on wheat yields (Singh *et al*., 2005; Bijay-Singh *et al*., 2008) but in 4th year the impact was noted concerning residues incorporation (Gupta *et al*., 2007).

Similar results were indicated by several other researchers also. The incorporation of rice straw resulted in N immobilization into soils under anaerobic conditions (Pathak *et al*., 2006; Cucu, 2014), and ascribed to decline in rice yield (Schmidt *et al*., 2004). Other findings by Singh *et al*., (2009) showed the reaction of wheat to N application for optimum yield was affected by many years of residue assimilation (Thuy *et al*., 2008; Singh *et al*., 2009).

Negligible contribution of nutrients from residue of crops mostly supplied by applying fertilizers causing increase in yields was justified from the experiments of Bijay-Singh *et al*., 2008. Analogous consequences were also reported by Bahrani *et al*., (2002) and Singh *et al*., (2004) with indication of that due to N immobilization, grain yield was lesser in the treatments with residue incorporation before sowing the next crop, than the plots where residues were removed or burnt. Other scientists (Walia *et al*., 1995; Singh *et al*., 1996; Singh and Singh, 2001) also reported no difference of rice and wheat yields under varied residue management techniques. Lingan (2015) exposed increased retention of maize residues without proper soil management could cause short-term nitrogen immobilization and rapid moisture loss in soil. Several other long-term studies emphasized that nitrogen added by wheat straw incorporation will not fulfill the requirement of nitrogen in rice.

Crop production was not significantly affected by the varied residue management options. While, during trials, grain yield was significantly lesser for reduced tillage as compared to conventional/common tillage practices (Hiel *et al*., 2018) after conducting experiments with four residue management practices on three crops.

Assessment of the effect of 84 years of residue and fertilizer management on nutrients availability and uptake in winter wheat-fallow rotation in the long-term experiments at the Columbia Basin Agricultural Research Center at Adams, OR showed that that residue burnt and no burnt treatments have similar impact on macronutrient in soil and wheat. Nitrogen applied @ 90 kg/ha reduced accumulation of Phosphorous, Potash, and Calcium in grain, but had higher grain N accumulation (Shiwakoti, 2018).

For attaining crop growth and yield increment, early sowing can be the best option. Selection of optimum dates of sowing for different sites depend on weather trend and crop growing period of the specific variety of wheat (Qasim *et al*., 2008). Timely sowing led to more germination, increase in growth attributes, number of grains and seed index compared to delay planting (Shafiq, 2004). Higher crop yield was observed with optimum sowing time periods (Baloch *et al*., 2010; Said *et al*., 2012). Yan *et al*., (2008) registered highest yield in timely sowing wheat with more proteins.

Significantly higher tiller count, dry matter, CGR, LAI, spike number, grain number in each spike and yield by wheat sowing on 25th November than sown on 20thDecember was advocated (Alam *et al*., 2013).

Delayed sowing resulted in less tiller count as the crop faces less temperature. For delayed planting short duration cultivar of wheat would able to escape from increased temperature at the grain filling stage (Phadnawis and Saini, 1992). Early sowing led to higher productivity due to longer growing period than late sown (Munir *et al.,* 2002*;* Tanveer *et al.,* 2003) and sound growth linked with quick and homogeneous appearance , larger size and more tillers. Tripathi *et al.*, (2005) confirmed that sowing wheat beyond November 15 resulted in a yield decline @ 0.27 q ha^{-1} daily.

Highest grain yield was obtained by sowing on 1$^{\mathbf{st}}$ December compared to 30th December at Faisalabad, Pakistan (Tahir *et al*., 2009). The early sowing gave higher grain yield in comparison to late sowing (Tomar *et al*., 2014). During grain filling in wheat crop, terminal heat stress imposed adverse effect that was mitigated by early sowing and residue retention (Balwinder-Singh *et al.*, 2016; Gonsalvez, 2013; Gathala *et al.*, 2011). Simulations by Balwinder-Singh *et al.,* (2016) predicted that lower wheat yields were obtained under mulched or non-mulched field when sown on 15th November compared to wheat under mulched conditions sown on 31st October in Punjab.

Wheat sowing from 4th Nov.- 19th Nov. produced higher yield under subtropical region of Jammu (Mahendra *et al*., 2017). It was pointed out that much improved grain yield in wheat was obtained in case of wheat planting in first week of November and it was at par with 3rd week of November planting. Yadav *et al.*, (2017) indicated from a field experiment conducted at Bijnour, U.P that wheat which was sown earlier produced higher grain yield compared to late sown wheat crop.

An experiment conducted in HAU, Hisar by Yusuf *et al*., 2019 highlighted the importance of early sowing in wheat and reported higher grain yield and B:C ratio of 5th November sown wheat as compared to other sowing dates. Andarzian *et al*., 2015 stressed the importance of appropriate time of sowing in wheat on its grain yield by highlighting that heat stress constraint for late sowing crop revealed from the trial conducted in Iran. Gupta *et al*., 2017 reported maximum reduction in yield attributes and yield of wheat in Uttarkhand with sowing on 6th January compared to Ist and 20th December of crop sowing.

2.2.1.2 Soil health

Not only crop growth and yield improved with residue management strategies in a cropping system but the roots of increase extend up-to soil well being or soil health. Soil, which is the basic nutrition supplier, can be made healthy by application of organic sources, less tillage, protection from erosion, avoiding extra use of chemicals and also by appropriate crop residue management options.

For maintaining carbon to nitrogen ratio in soil, different nitrogen levels and crop residue rates are the practically possible techniques as the ratio is the key factor in determining the effects of residue incorporation on nutrients availability in soil. The soil microbial biomass shows the soil's capability to store and recycle the nutrients as well as organic matter for physical stabilization of aggregates. Soil microbial biomass (SMB) based on the presence of organic compounds in the soil and affects nutrients viz. N, P, and sulphur availability.

Retention of crop residues with proper fertilization for longer period of time could perk up soil fertility and crop productivity revealed by Malhi *et al*., (2011). However, fertility of soil was consistently more with crop residue compared to residue removal treatments observed by Salih *et al*., (2012). Verma and Bhagat (1992) indicated that addition of residues increased soil O.M. (organic matter), increased N mineralization potential (Bacon, 1990) and continuously increased microbial biomass by straw incorporation for many years rather than burning (Bird *et al*., 2001; Powlson *et al*., 1987). In a rice-wheat scheme, Beri *et al*., (1992) and Sidhu (l995) found five to ten times higher bacteria and fungi in soil applied with crop left over than soil where residues either burnt or removed.

Soil residue incorporation has encouraging effects on the soil health. pH of soil significantly decreased by retaining residue of maize (Bai *et al.,* 2011), mainly due to higher microbial growth caused an enhancement in wheat growth, especially in alkaline type of soils. Patra *et al.,* (1992) reported higher carbon biomass in wheat residue and higher biomass nitrogen in cowpea residue-amended soil. Malik *et al*., (1998) observed huge microbial biomass enhancement in rice by wheat straw plus green manure incorporation.

Declined soil microbial biomass with lesser quantity of residue retention on the surface of soil was indicated by Verhulst *et al.,* (2009). Better soil O.C. through retention or incorporation of crop left over was achieved by replenishing the required carbon and nutrients back into the soil (Singh *et al*., 2014; Bera *et al*., 2018; Jat *et al*., 2018). Increase in soil microbial population led to the conversion of unavailable form of nutrients to available form (Bisen and Rahangdale, 2017).

The hard pan in rice wheat system was reduced by the retention of rice residue in wheat (Singh *et al*., 2005). Crop productivity enhancement, improved soil health with more water and nutrient use efficiency was attained by retaining crop residue on earth’s surface associated with organic manure and legumes (Sainju *et al.*, 2008).

For rice-based systems in India, for sustaining the soil organic carbon, critical limit of carbon requirement has been calculated as 2.47 tonnes per hectare per year (Srinivasarao *et al*., 2013). Regar *et al.,* (2005) revealed increased carbon content, available N and P in soil by incorporation of crop residue. Verma and Pandey (2013) reported increased O.C % by rice residue inclusion significantly. Malhi *et al*., (2011) and Noack *et al*., (2014) also registered the same findings with residue inclusion than burning rice straw or its removal.

Highest percentage of organic carbon and total nitrogen in treatments with residue incorporated comparing to residue burnt or removed in rice–wheat was noticed (Beri *et al*., 1995). Analogous reporting was done by Sharma *et al*., (1987) after six years of study and Zia *et al*., (1992) in three years' study period. Increased availability of nutrient was reported by long-standing incorporation of rice straw in tropical regions (Ponnamperuma, 1984; Verma and Bhagat ,1992) related condensed nitrogen need with higher yields. Wheat residue incorporation with farm yard manure and higher levels of nitrogen augmented the major nutrients availability was reported by Bhat *et al.,* (1991).

Labile fractions of soil organic carbon measurement can be a more perceptive signal of residue management and tillage effects on soil quality (Franzluebbers and Arshad 1997) and glomalin content contributing towards carbon pools and related to C-sequestration (Rillig *et al*., 2003; Lovelock *et al*., 2004; Rillig *et al*.,1999). Applied rice straw-C @ 12-25% was sequestered by the soil based on the carbon applied and variation in soil carbon content (Singh *et al*., 2004, 2009) in three to seven years study.

Twenty - six percent decrease in soil O.C. through burning of crop residue within the last 40-50 years was reported (Gollany *et al*., 2011; Peacock *et al*., 2001; Rasmussen and Parton, 1994) and ammonia volatilization occurred by higher urease enzyme activity in the ash present on the soil surface which is alkaline in nature after flaming crop residues (Bacon and Freney, 1989).

Rice residues are also the rich source of potash and release about seventy percent of potassium in 10 days after soil inclusion (Singh *et al*., 2010a). About 80% micronutrients started from 50% utilized by rice and wheat crops might be reused by included residue (Singh *et al*., 2005; Gupta *et al*., 2007).

On-farm rice straw inclusion 10-20 days advanced wheat planting was said to be successful in crop to avoid nitrogen immobilization and increasing nitrogen availability

(Singh *et al*., 2004). Significantly more uptakes of nutrients were noticed in maize-groundnut system by crop-residue treatments (Rosenani *et al*., 2003).

Although, Misra *et al.*, (1996) observed increased accessibility of major nutrients with crop residues incorporation for Bihar, in an another study, conducted from 2009-2012 in Pantnagar, very small upgrading in soil O.C. content by residues incorporation was observed by Pandiaraj *et al*., (2015), perhaps owing to sluggish comeback of organic content in soil due to management practices and less precise measurement in short time span as recommended by Langdale *et al*., (1990) and Power *et al*., (1998).

Different straw management strategies had no effects on grain yield of rice, but N uptake increased by 5 years' incorporation studied by Eagle *et al*., (2001). With increasing uptake of nitrogen, C: N ratio increased so the initial N fixation capacity as reported by Kuo and Jellum (2002) and Kuo *et al*., (1997). Gupta *et al*., (2007) reported increased inorganic, organic phosphorous and increased P release by incorporation of residues.

Nitrogen use efficiency is approximately 33% worldwide for cereals and it is influenced by different crop types, N fertilizer dose, temperature and soil situation (Raun and Johnson (1999); Halvorson *et al*., (2001). Increased dry matter and NUE was noticed with residue inclusion compared to residue removal system (Zhao and Chen, 2008) and difference was significant with application of N @270 kg/ha. Yamoah *et al.*, (1998) after studying N efficiency indices concluded that, efficiency was lesser in monoculture systems compared to crop rotation systems and these indices decreased with increasing nitrogen levels, particularly for dry soil (Huggins and Pan, 1993).

Nitrogen efficiency significantly affected by nitrogen levels and crop rotation suggested by Lopez-Bellido (2001). Bijay-Singh *et al*., (2001) found the maximum recovery of labeled nitrogen in wheat when applied @ 30 kg /ha with straw inclusion into the soil than its burning or removal. Sowers *et al.*, (1994) reported poor N uptake and NUE by the appliance of elevated N rates. Kumar *et al*., (2000) found higher uptake of nitrogen by increasing nitrogen levels in Bihar. Similar findings were given by Dwivedi and Thakur (2000).

Application of 33% nitrogen during wheat residue incorporation, rest two-third at other two phonological levels increased the grain and straw yield, N uptake, apparent N recovery and agronomic efficiency of N indicated by Sharma (2002). Dahri *et al*., (2018) revealed that the time of straw incorporation of previous crop affected SOM marginally. These results comply with Memon *et al.,* (2018), who found increased soil organic matter significantly by straw incorporation.

Residues retention increased wheat grain and straw yield. Grain and straw N uptake increased by 1.32 and 1.67 respectively in treatments with crop residues retention as compared to residues removed (Pandiaraj *et al*., 2015). The results of the study are analogous to Stevenson and van Kessel (1996) may be accredited to nitrogen availability from residues of crops due to soil health up gradation.

Improved N mineralization and N use efficiency and reduced N leaching losses were reported after soil amendment with straw (Huang *et al*., 2017; Zhao *et al*., 2014; Wang *et al*., 2014). Sharma *et al*., (2019) conducted a trial at PAU, Punjab for studying the impact of crop residue retention on carbon content of soil in R-W cropping scheme and described that incessant use of residue based sources of carbon enhanced the activity and profusion of microbes in soil leading to high soil carbon pools in zero tilled wheat.

Straw incorporation increased soil available major nutrients and organic carbon as compared to straw removal. Activities of soil enzymes like urease, catalase and invertase also increased in the top layer (Zhao *et al*., 2019). Increase in soil nitrogen was indicated by residue incorporation (Pandiaraj *et al*., 2015; Kumar and Goh 2002; Surekha *et al.*, 2003) in different experiments. Ali *et al.*, (2019) in Pakistan observed that residue incorporation led to higher major nutrients' uptake in rice and wheat compared to other practices like residue burning, residue removal and zero tillage.

Decreased nitrogen efficiency with increasing nitrogen levels was observed by Anderson (2008), Huggins and Pan (1993) and Sowers *et al.,* (1994). Rahimizadeh *et al*., (2010) observed that NUE of wheat at maximum rate of nitrogen was smaller than the control. Yajie and Zhang (2017) found that agronomic efficiency, partial factor productivity and nitrogen physiological efficiency in rice treatments applied with higher dose of nitrogen were significantly lesser than other practices.

After investigation done from a field trial by Murtaza *et al*., (2017), they observed highest crop yield and NUE nitrogen when applied 30% extra than recommendation along with gypsum for saline-sodic soils also supported by Havlin *et al*., (2005) who reported similar type of results. However, excess N fertilization might cause loss of SOC due to better crop residue decomposition (Mulvaney *et al*., 2009).

The earlier belief can be debated because studies have found that N fertilization had slowed the SOC loss compared to no N fertilization (Ladha *et al*., 2011). The immobilization of nitrogen and decrease in its loss by residue incorporation was indicated (Wang *et al*., 2015) by chemical and biological processes (Bengtsson and Bergwall, 2000) specifically, the speedy increase in microbial immobilization of inorganic N fertilizer (Bird *et al*., 2001). Phongpan and Mosier (2003) reported that organic sources did not affect grain yield and nitrogen use efficiency in rice significantly.

No effect of residue management was reported by Brennan *et al*., (2014) on N and P uptake in plants, however pessimistic effect was indicated (Soon and Lupwayi, 2012 ; Damon *et al*., 2014).These variations are normally attributed to variation in residue quality, soil texture or initial nutrient status of soil (Kumar and Goh, 1999; Chen *et al*., 2014).

Poeplau *et al.,* (2015) showed less or no affirmative effect of straw incorporation. Brar and Walia (2008) however, reported statistically similar economical yield and nutrient absorption by wheat under all rice residue management techniques in a field trial (2004-2006).

2.2.1.3 Economics

Management strategies to increase NUE of cereal production systems must also consider recovery efficiency of nitrogen and physiological efficiency of nitrogen because these parameters determine the economic impact on grain yield in relation to applied N inputs and crop- N accumulation. Late sowing of wheat due to climatic, water or some other management obstacles like rice residue removal, retention or incorporation prone to major dip in grain yield, so the net returns also.

A discrete attribute of the R-W system is the intrinsic clash amid increasing short-term yield at least cost (Kumar and Goh, 2000). Kenneth *et al*., (2002) stated a huge impact of B: C ratio on farmers' acceptance of new techniques.

Wheat sown on end of November month achieved higher net income and benefit cost ratio (1.34) almost 90% higher than delayed sown wheat as indicated by Alam, *et al*., (2013). Shabnam *et al*., (2018) also found highest benefit cost ratio to the tune of 2.01 by sowing wheat crop on 15^{th} November owing to higher yield attributes and yield.

Wheat under varied levels of N and methods of placement was analyzed by Lakho *et al*., (2004) and they got higher yield of wheat by applying N @ 48 kg for an acre and with higher economic returns also. Kumari *et al*., (2018) observed higher grain yield and economic benefits dependency on nitrogen levels in finger millet.

Farmers were benefitted from residue burning @ 108-113 USD per hectare due to 9% higher productivity and 10% lesser cost of cultivation as indicated by Haider (2012) from the study conducted in Bangladesh on options for managing crop residue. Kumar *et al*., (2015) reported that 66-75% of rice residues are burnt in the field due to the absence of other economical option available to the farmers.

A study under a research project in Philippines on economic analysis of rice straw management alternative and reported that out of three alternative (residue burning, incorporation and removal), highest grain yield (5.04 units/ha) was produced under residue burning compare to residue removal (4.65 units/ha) and the least (3.70 units/ha) in residue incorporation treatment. Further, economic analysis showed that early stubble and straw incorporation gave the economic benefit of Rs.1877/ha/year as compared to late stubble incorporation and straw burning i.e. Rs.2746/ha/year (Launio *et al*., 2015).

In Bangladesh, practicing crop residue was more productive in terms of net income and yield in each hectare of land (Uddin and Fatema, 2016). In case of without rice crop residue, the BCR of rice farming was 1.3, and it was 1.6 for crop residue condition. Lohan *et al*., (2017) observed ex-situ management of rice residue as uneconomical alternative due to cumbersome act of collecting and transporting it out of the field.

The use of Happy Seeder technology was more economical compared to conventional method in Punjab with the net saving of Rs.950 per acre was revealed by Roy and Kaur (2016) from the survey of 20 farmers. Sidhu *et al.,* (2007) indicated that total financial benefits by using Happy Seeder were higher Rs. 10,150/ha compared to residue burnt + zero tillage in wheat crop and Rs. 32,750/ha higher than the residue burnt +conventional tillage.

2.2.2 Crop yield evaluation through crop modeling

Anthropogenic activities like burning of fossil fuels, exhausts from industries, burning of crop residue etc. increased emission of green house gases in the atmosphere leading to adverse effects of climate change to become worse. Agriculture, which is the product of climate and soil affected through floods, droughts, heat waves, cold waves, hailstorms, thunderstorms, etc. Therefore it is imperative to study these impacts of weather on crops and suitable management strategies to be adopted or the ways to mitigate the adverse changes due to weather calamities.

Crop models play a crucial role in this climatic change scenario as it seems unwise to waste natural resources on field experiments every time to find better solutions to the current also by keeping in view the predicted rainfall and temperature changes.

In recent times, models were particularly developed for simulating annual crops (Wang *et al*., 2015; Gou *et al*., 2017; Liu *et al*., 2017), with specific emphasis on the time based progression of their stages. InfoCrop model was evaluated and calibrated (Akula and Shekh, 2005) for wheat crop at Anand by giving an indication of feasibility of taking higher wheat yield. InfoCrop was calibrated and validated for wheat (Haris *et al*., 2011; Haris *et al*., 2013), rice (Haris *et al*., 2013; Elanchezhian *et al*., 2012), maize (Haris *et al*., 2015), chickpea (Haris and Vandna, 2014) and potato (Haris *et al*., 2015) crops and predicted yields for future scenarios in different agroecological zones of Bihar.

Crop models and their use for land use systems in Bihar was studied (Bhatt *et al*., 2014). Crop models, such as APSIM, CROPSYST, FASSET and STICS having sub-modules for showing struggle for abiotic factors (Chimonyo *et al*., 2015).

In Australia, climatic risk was quantified with relation to sorghum crop (Hammer and Muchow, 1994). Nitrogen requirement was assessed by maize crop through CERES-maize model in Nigeria by Amissah-Arthur and Jagtap (1995). Hammer *et al*., (1995) and Clifford *et al*., (2000) successfully estimated the groundnut productivity by using the models.

A decent agreement between simulated and actual yield while using CERES-Rice at Pilicode was found by Rao and Subash (1996). Saseendran *et al*., (1998) obtained appropriate rice transplanting time by using CERES-Rice and ClimProb in Kerala.

YIELD model for estimating productivity in boro rice and reported it as promising under normal and abnormal climate scenarios in Bangladesh by Mahmood (1998). Hundal and Kaur (1999) evaluated CERES-Rice model for agronomic practices in rice and showed that the optimum date of transplanting for rice as 15 June.

Dependence of phenophases in pigeonpea upon the available growing degree days for Anand, Gujarat was reported (Patel *et al*., 1999). Kumar *et al.*, (1999) developed a model for pigeonpea yield and reported more than 90% variation with weather change, however, Mall *et al*., (2000) emphasized wheat yield and weather relationship in the Varanasi district of Uttar Pradesh. At Coimbatore predicted grain yield through CERES-Maize a good agreement in simulated and observed values was reported by Karthikeyan and Balasubramanian (2005). Rai and Kushwaha (2005) validated the CERES-Rice model for predicting yield of upland rice at Pantnagar and reported that the simulated and observed duration for panicle initiation and 50% flowering were predicted well.

CERES-Rice v.3.5 and CROPGROW –Chickpea crop growth simulation models were used (Singh *et al*., 2005) for finding the probability of second crop in agro climatic zone of the Bastear plateau. It was reported that the yields of rice sown on 15^{th} and 22^{nd} May were more. For chickpea, higher yield was obtained by sowing on 4^{th} October under irrigation. Chaudhari *et al*., (2005) indicated SPAW model as a device for irrigation scheduling under irrigated wheat.

CERES-Rice and CERES-wheat model were calibrated by Sharma and Kumar (2005) and it was reported that the phenology and yield was simulated well by the models. Das *et al.*, (2007) used ORYZA 2000 in West Bengal successfully. Launay *et* *al.,* (2009) used STICS for assessing pea-barley for improving NUE. Crop models with soil module and residue management could simulate N and carbon. Bertrand *et al.* (2018) indicated root systems representation within the soil profile through BISWAT or STICS models.

General Circulation Models (GCMs) combined with crop simulation models can be used for optimum crop designs and reducing risks as reported by Rodriguez *et al*., (2018) while, Fletcher *et al.,* (2015) demonstrated yield improvements in following wheat by nitrogen fixation through wheat-pea intercropping.

Chapter-III

MATERIAL AND METHODS

A research experiment was carried out in to evaluate wheat establishment methods concerning sowing schedules and nitrogen levels in wheat. The materials used and methodologies practiced during the exploration are presented.

3.1 Location of research experiment

The experiment was performed at farmers' field in Fatehgarh Churian, District Gurudaspur, Punjab (India) during *rabi* season 2018-19 and 2019-20. The site of the experiment was situated at 31°51'N and 74°57'E and at 234 m height from mean sea level in Punjab. The location of experiment comes under Central Plain Zone of Punjab (Fig 1).

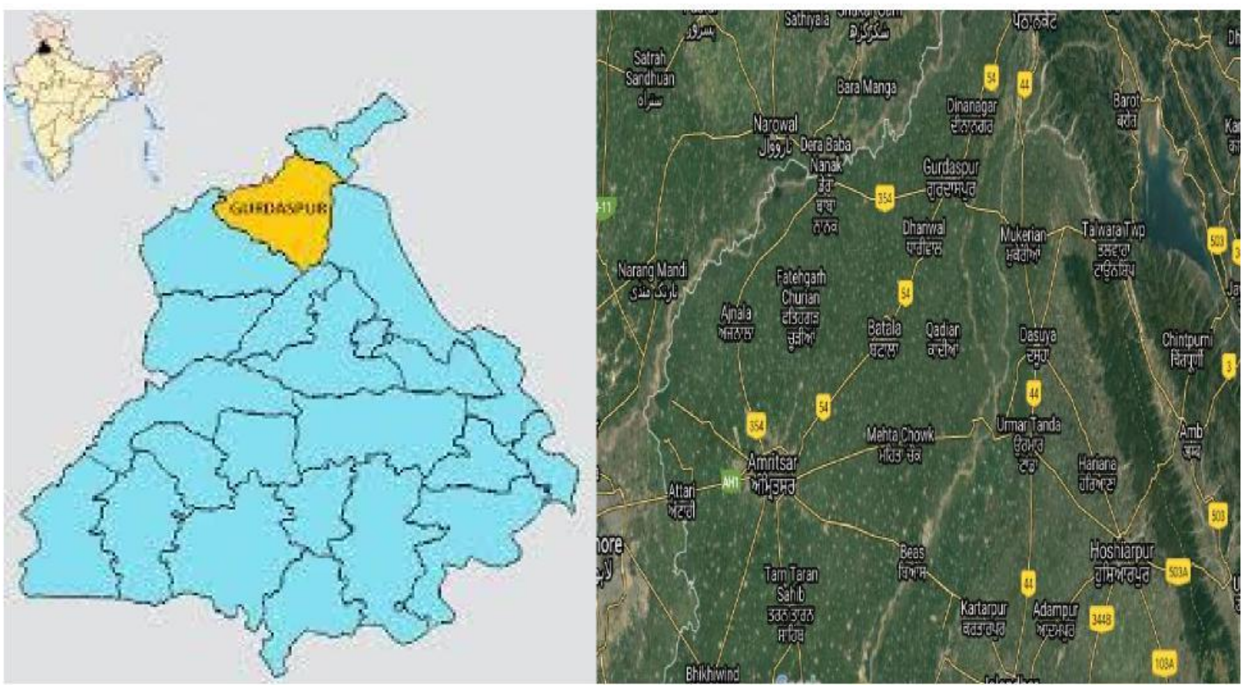


Fig 1. Location of the experiment

3.2 Soil characteristics of experimental site

Randomly taken soil samples from selected plot to a depth of 0-15 cm and by mixing them all a composite sample was finalized. These were then dried and sieved through 2 mm sieve for analysis. The values along with methods employed for measuring chemical properties of soil are presented in Table 1.

Table 1. Chemical properties of the soil in experimental area

S.No.	**Property**	**Value**	**Method employed**
Chemical properties			
1	Electrical Conductivity (dSm^{-1})	0.53	Systronics Electrical conductivity meter
2	pH (1:2.5 soil water suspension)	7.2	Glass electrode pH meter
3	Organic carbon (%)	0.43	Walkley and Black's technique
4	Nitrogen (kg ha^{-1})	258.7	Subbiah and Asija, 1956
5	Phosphorus (kg ha^{-1})	14.7	Olsen *et al*., 1954
6	Potassium (kg ha^{-1})	50.4	Black, 1965

3.3 Weather situation

Weekly average of weather variables such as maximum & minimum temperature, rainfall, relative humidity (R.H), solar radiations and wind speed recorded from website. The climatic conditions prevailed during the crop seasons in the years of experimentation (2018-2019 and 2019-2020) are depicted through Fig. 2 (a-f). The varying temperature conditions were observed during the crop seasons viz. 2018-19 and 2019-20. The mean maximum temperature of the study site was 39℃ and minimum temperature was 6°C for the year 2018-19. However these values were 41°C and 3°C in 2019-20.

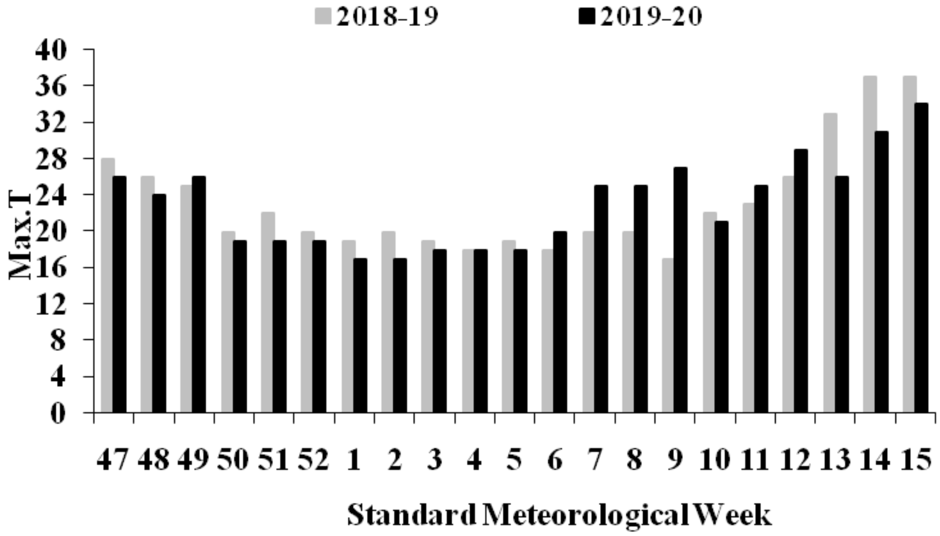


Fig 2 a. Average weekly maximum temperature (°C) during crop seasons of 2018-19 and 2019-20

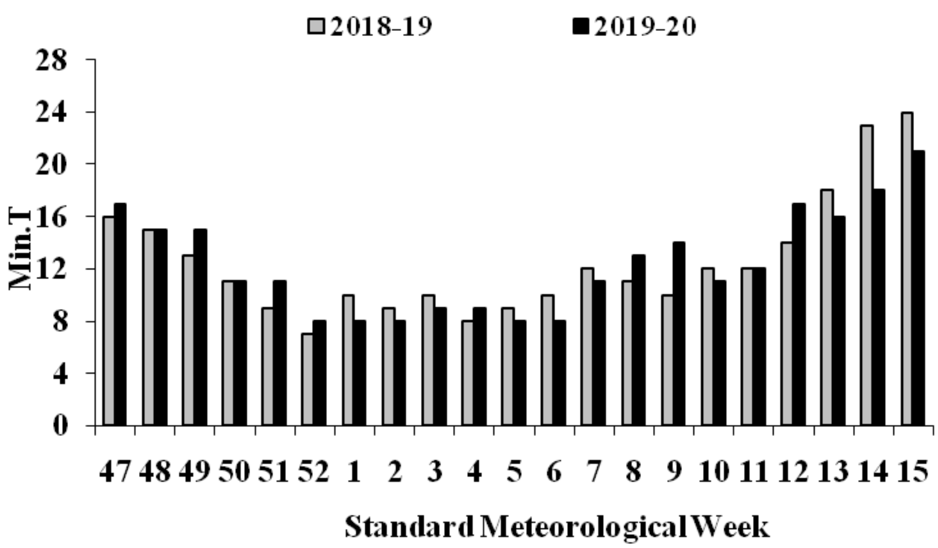


Fig 2 b. Average weekly minimum temperature (°C) during crop seasons of 2018-19 and 2019-20

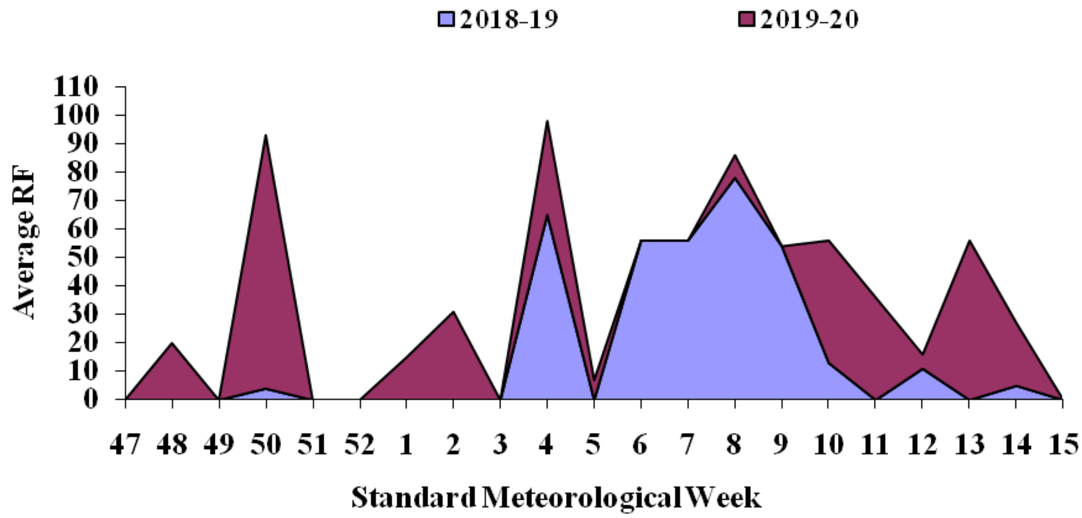


Fig 2 c. Average weekly rainfall (mm) during crop season during 2018-19 and 2019-20

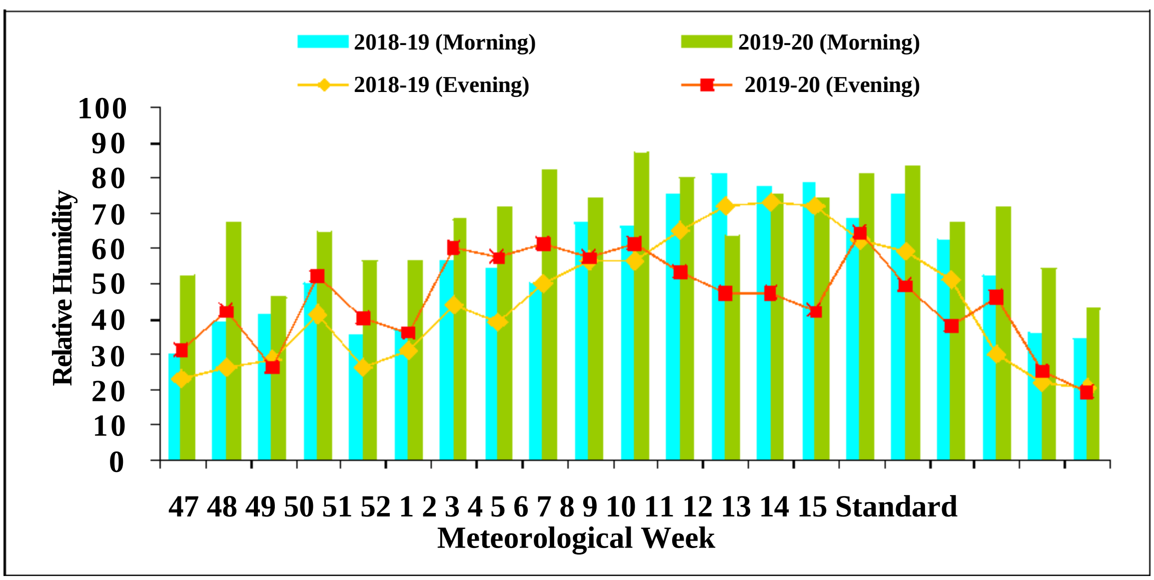


Fig 2 d. Average weekly R.H (%) during crop season during 2018-19 and 2019-20

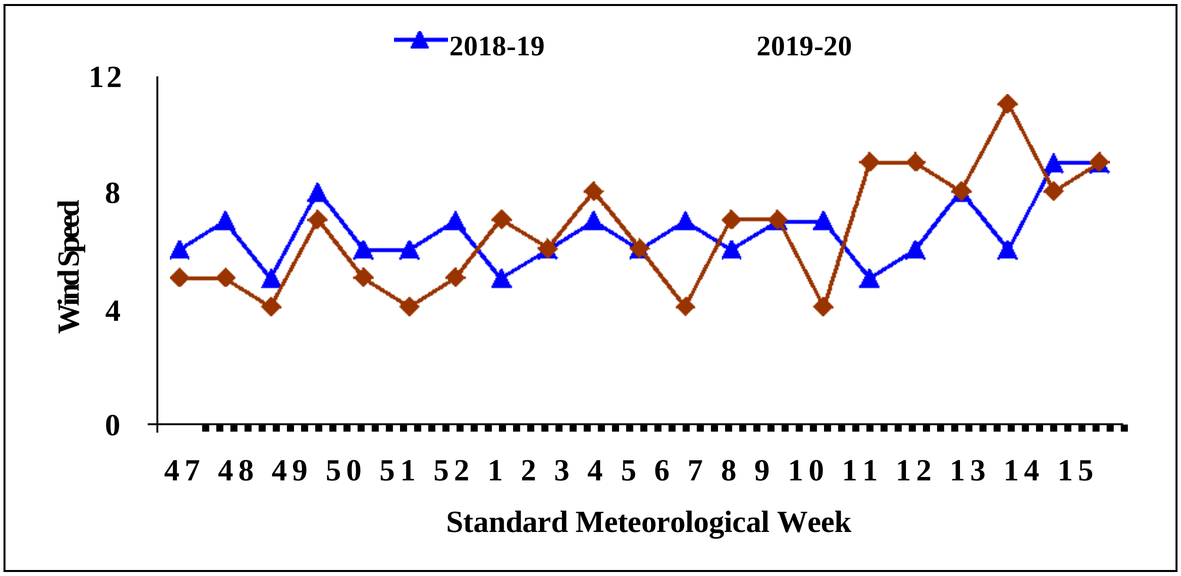


Fig 2 e. Average weekly wind speed (Km/hr) during crop season

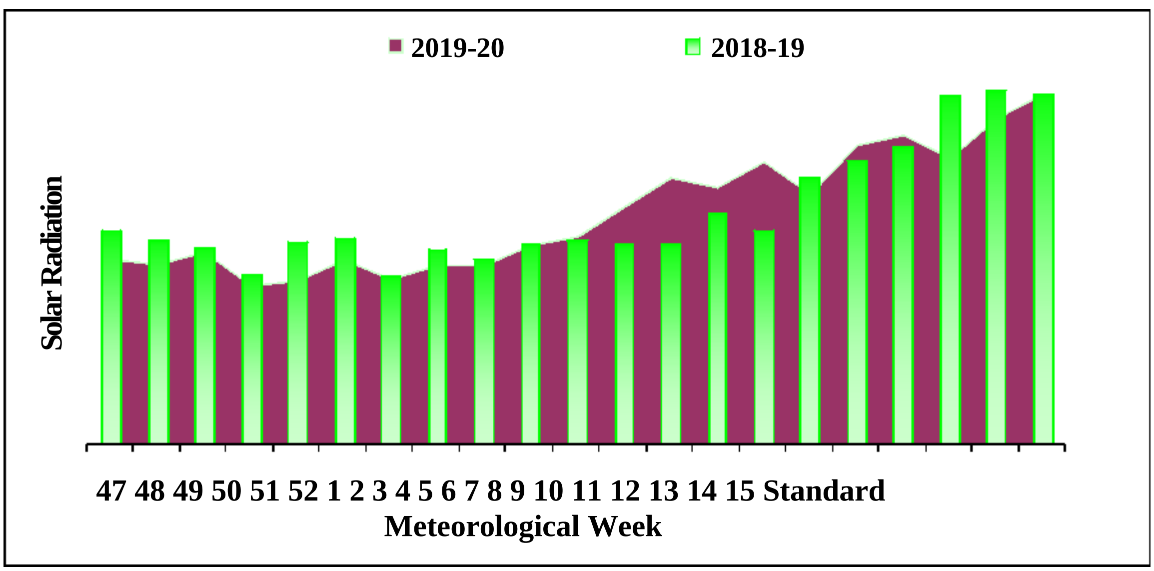


Fig 2 f. Average weekly solar radiations (MJ/m2) **during crop season**

Gross rainfall received for the duration of crop was 393mm and 365mm respectively during 2018-19 and 2019-20 (Fig 2c). Though the amount of rainfall didn't differ so much from first to second year, but almost ten weeks got the rainfall out of 21 weeks of crop season during 2018-19 and highest amount was during 8th standard meteorological week (SMW) i.e.78 mm followed by 4th SMW. However, 13 weeks out of 21 received rainfall with maximum amount (89 mm) during 50th SMW followed by second highest 56 mm in 13th SMW in 2019-20.

Average relative humidity (R.H) remained 54% during 2019-20 and 50% almost during 2018-19 (Fig 2d). Weekly average wind speed trend during the crop seasons is presented in fig 2e and solar radiation average amount recorded was 13820 MJ/m^2 during 2018-19 and 14695 MJ/m^2 (Fig 2f).

3.4 Experimental details

I. Field experiment

For a field experiment during *rabi*, test crop wheat (*var*. HD-3086) was laid out during the years 2018-19 and 2019-20 in the same plot with same treatment combinations.

3.4.1 Design and layout

The field experiment was laid out in split-split plot with randomized subplots having twenty seven treatments replicated thrice.

3.4.2 Treatments Details

Year of Experiment- 2018-19 and 2019-20

Crop- Wheat (var. HD-3086)

Recommended Fertilizers -150:60:30 kg N, P, K /ha

Treatments -27

Replications -3

Total plots -81

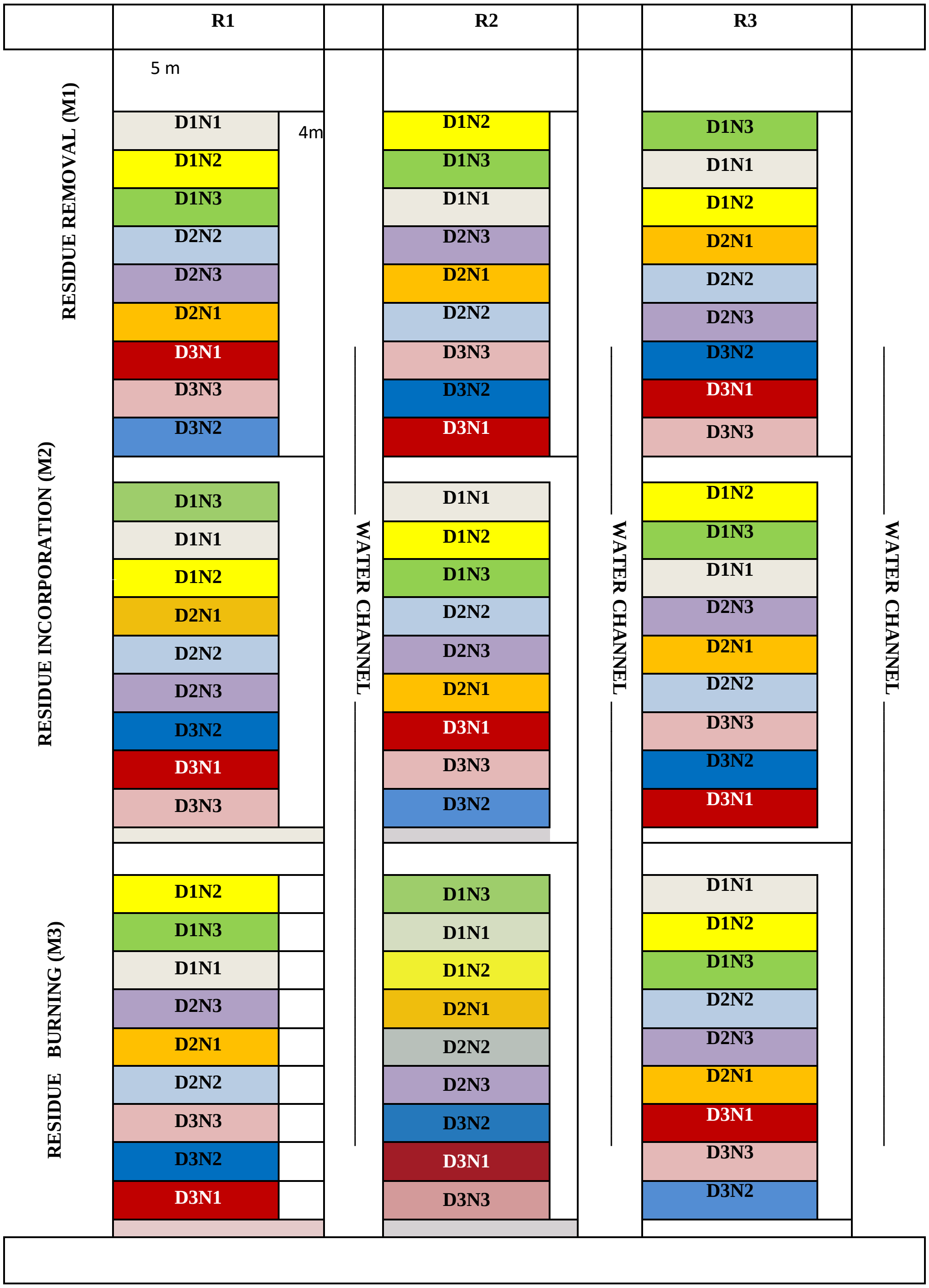
Plot size-20 m^2

Experiment design - Split-Split Plot Design

Method of Sowing- Line sowing

Treatment combinations

Treatments	**Treatment details**
Main plots	
Methods of crop establishment	
M1	Residue Removal
M2	Residue Incorporation
M3	Residue Burning
Sub plots	
Dates of sowing	
D1	20^{th} November
D2	5^{th} December
D3	20^{th} December
Sub plots	
Nitrogen Levels	
N1	50% RDN+ Recommended PK
N2	75% RDN+ Recommended PK
N3	100% RDF



3.4 Plan of layout of the experiment

3.5 Cultural operations

3.5.1 Field preparation

The experimental land was prepared after harvesting of previous paddy crop. Field was divided into three equal parts. One part of field was applied with water as a pre sowing irrigation (*rauni*) then ploughed by disc harrow once, twice by cultivator and then followed by planking (Residue removal). Second part of field was prepared by running rotavator twice for incorporation of paddy residue.

Plate 1: Land preparation for sowing of wheat after rice residue management

In the third part, farmer burnt the residue of the previous crop by open firing, and then it was irrigated and cultivated making the land prepared. Then the layout of field was done.

3.5.2 Sowing, fertilizer application, irrigation and weeding

The required amount of seed of HD 3086 variety was taken @100 kg ha^{-1} and sown by line sowing method as per the timing of sowing.

The optimum sowing time for this variety is from 4^{th} week of October to 4^{th} week of November month. At sowing, half quantity of nitrogen along and whole quantity of phosphorous and potassium according to treatment was applied. The remaining dose of urea applied after first irrigation. Urea, DAP and MOP were applied to provide nutrients in the form of NPK respectively.

Plate 2: Wheat crop at vegetative stage

Crop was irrigated 4 times depending upon rainfall occurrence. During 2018-19 first (Ist) irrigation was given 21 days after wheat sowing. Second irrigation was applied after 5^{th} week from first irrigation and subsequently irrigations were given as per the need. During 2019-20 first irrigation was applied at CRI stage and second irrigation was applied after 5^{th} week and subsequent irrigations thereafter.

Weeds were controlled with the help of mechanical method viz. hand hoeing. Two hand hoeing were done to control weed population, first weeding before first irrigation to crop and second after irrigation.

Plate 3: Wheat crop at maturity stage

3.5.3 Harvesting

Crop was harvested after 140-150 days with the help of sickles. One m^2 area was harvested for getting biomass from the net plot size. After harvesting the produce was dried under sun for facilitating threshing. Threshing was performed with hands and grains were separated from the spikes and dried properly at 18% to 20% moisture level.

Plate 4: Harvesting process in wheat crop

3.6 Collection of experimental samples

3.6.1 Soil sampling

Prior to next sowing, samples of soil were collected from 5 different spots in each plot and then a composite sample was prepared.

3.6.2 Plant sampling

Plant samples were collected at 30, 60, 90, 120 days after sowing, at maturity and after harvesting. Five plants were randomly selected from each plot. Collected plant samples washed, air dried and stored in poly packs for analysis.

3.6.3 Growth, yield and yield contributing parameters

3.6.3.1. Plant height (cm)

Observations were taken at intervals of 30, 60, 90 days after sowing and at harvest time commencing from ground level (base) to the top of spike in centimetres.

3.6.3.2 Tillers per plant

For its assessment, 5 randomly selected plants were taken at intervals of 30 and 60 DAS.

3.6.3.3 Spikes per plant

Again randomly chosen plants from each plot were taken and their number per plant was observed at reproductive phase.

3.6.3.4 Length of spikes (cm)

Randomly selected plants were measured lengthwise with meter scale.

3.6.3.5 Number of grains per spike

Grains number per spike was recorded by choosing 5 plants at random and threshed carefully for grains per spike.

3.6.3.6 Weight of 1000- grains (g)

Weight of 1000 grains (Seed index) was noted in grams.

3.6.3.7 Grain yield (t ha^{-1})

The crop was harvested as per treatment at physiological maturity phase. The threshing of grains was done, and then dried in sun for 2-3 days then calculated yield.

3.6.3.8 Straw yield (t ha^{-1})

It was evaluated by subtracting total grain weight from total above ground biomass.

3.6.3.9 Harvest index (%)

The harvest index was calculated by using the formula given below:

Harvest Index (%) = (Grain yield/Biomass) x1 00

3.7 Methods of chemical analysis

3.7.1 Soil analysis

3.7.1.1 Determination of soil pH and EC

Dry soil was taken and weighed 10 g then transferred to a beaker (100 ml) then distilled water to the amount of 25 ml was added and stirred four times by a glass rod and kept for 30 minutes for attaining equilibrium. pH meter was calibrated by using standard buffer solutions. After that stirring of soil suspension done and pH was recorded by using pH-meter and EC value was also recorded by conductivity meter (Jackson, 1958).

3.7.1.2 Organic carbon

To determine organic carbon in soil, 1 g of dried soil samples were weighed and taken into 250 ml conical flasks, to which I0 ml of 1 N potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml of concentrated H_2SO_4 was added. The content was shaken for a minute and was left for half an hour for completing reaction. Then 200 ml of distilled water, 10 ml of ortho phosphoric acid (85%) and 1 ml of diphenylamine indicator added and the violet color appeared in the suspension. The obtained solution was titrated with ammonium ferrous sulphate and the point of the titration was marked with the change of color from purple to green. The blank sample (without soil) titration was performed in the same way (Walkley and Black, 1934).

3.7.1.3 Available N

For the observation, 5 g of soil sample was taken in digestion tube, loaded the digestion tube in distillation unit and kept 20 ml of 2% boric acid in 250ml conical flask at other side of hose by mixing with indicator. 25 ml of $KMnO_4$ (0.32%) and 25 ml of NaOH (2.5%) solutions were added automatically by distillation unit programme. Liberated ammonia was collected in boric acid. The bluish green color solution collected titrated against 0.02N H_2SO_4. Blank sample was done similarly. From that nitrogen was calculated (Subbiah and Asija, 1956**).**

3.7.1.4 Available P

Available soil P was estimated by weighing dry soil (1 g) and put into conical flask (200 ml). 0.5 $NaHCO_3$ (20ml) + a pinch of Darco-60 were added to the same, contents shaken for 30 minutes with electrical shaker and contents filtered. A blank solution was also there. Then aliquot (5 ml) was kept into a flask (conical) and 5N H_2SO_4 (0.5 ml) was also added, shaken for a while until emission of CO_2 evolution stopped. Then ascorbic acid (4 ml) was poured and final volume made by adding distilled water. The intensity of the blue color developed within a calorimeter was recorded at 660 µm wavelength on spectrophotometer (Olsen *et al*., 1954)

3.7.1.5 Available K

Five gram dried soil taken into conical flask (150 ml), then ammonium acetate (52 ml) was added to the same. It was shaken for 4-5 minutes by mechanical shaker and filtered. The aliquot was collected and diluted with distilled water for making volume 25ml. Finally the reading was taken through flame photometer (Black, 1965).

3.7.1.6 Determination of Microbial Biomass Carbon (Jenkinson and Powlson, 1976)

Microbial biomass carbon was estimated by the fumigation process then contents become extractable in 0.5 M K_2SO_4. Six fresh soil samples were taken, two from each main plot (Residue removed, Residue incorporated, Residue burnt). Three soil samples from different treatments were kept without fumigation.

Other 3 soil samples were fumigated in the desiccators by using chloroform ($CHCl_3$). 20 g soil from each sample (Fumigated and Control) was extracted with 80 ml of 0.5 M K_2SO_4 in a conical flask for 0.5 hr on shaker and then filtered. The extract (8ml) was added to 2 ml of 66.7mM $K_2Cr_2O_7$ and 15ml of acid mixture (Sulphuric acid+ Phosphoric acid) and boiled gently for 30 minutes on a hot plate at temperature 150^{o}C and cooled for some time. After that, titration of mixture was done by using 33.3 mM Ferrous Ammonium Sulphate in 0.4M H_2SO_4 using 2-3 drops of Phenylthroline as an indicator. Calculations were done by using the equation.

Microbial Biomass Carbon (ppm) = (C fumigated-C control)

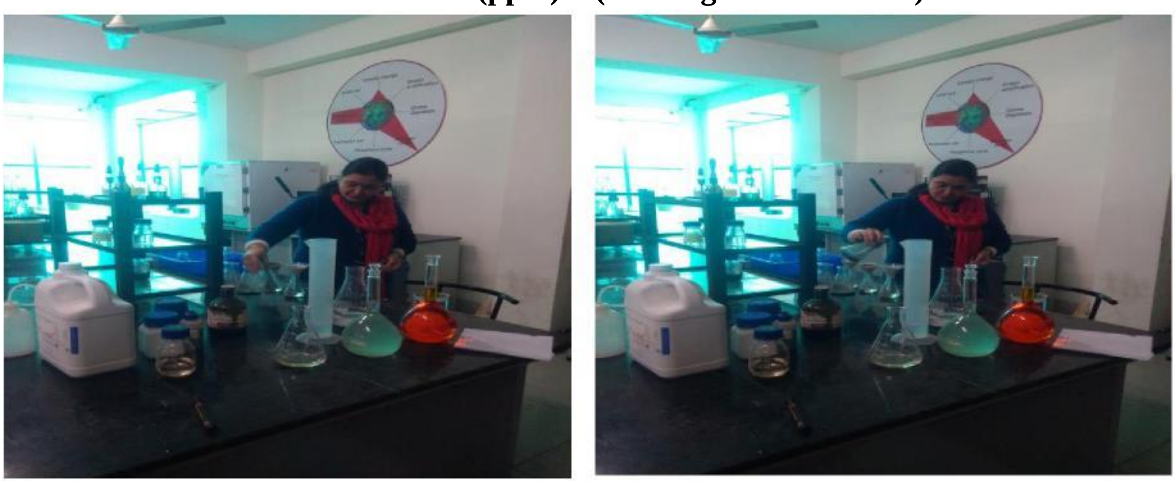


Plate 5: Laboratory analysis of microbial biomass carbon

Plate 6: Digestion of wheat grain samples

3.7.2 Plant analysis

3.7.2.1 Digestion of the grain samples

Grain samples were treated with diacid (HNO_3:$HClO_4$ in 10:4 ratios) mixture and kept for digestion. After completion of digestion process, transferred it to the flask (volumetric) and made volume with double distilled water and then filtered it. This sample was preserved for the P and K content in wheat grains. Kel plus instrument was used to analyze nitrogen in grains.

3.8 Nitrogen Use Efficiency

Total grain N uptake was calculated by multiplying total grain yields by their respective N content.

Nitrogen harvest index (NHI) representing the nitrogen use efficiency was estimated given by the procedure (Belete *et al*., 2018).

$$\text{NHI (\%)} = \frac{\text{N accumulated in grain}}{\text{The amount of N accumulated in grain plus straw}} \text{X100}$$

3.9 Economics

3.9.1 Cultivation cost (Rs ha^{-1})

Cost of cultivation was calculated by using the different agronomic practices and the inputs in a particular treatment.

3.9.2 Gross returns (Rs ha^{-1})

To work out the gross return, the prevailing market price was multiplied to grain yield and straw yield respectively.

3.9.3 Net returns (Rs ha^{-1})

It was calculated by

Net return= Gross return- Cost of cultivation

3.9.4 Cost: Benefit ratio

BC ratio was calculated on the basis of additional cost incurred on applying different inputs and additional output (GY) obtained due to the application of these additional inputs.

$$\text{B:C ratio} = \frac{\text{Net returns (Rs per hectare)/}}{\text{Total cost of cultivation (Rs per hectare)}}$$

3.10 Statistical analysis

Analysis of variance was done by Fischer's method by using OPSTAT software developed by HAU, Hisar and interpretation of the results was done. The level of significance was P=0.05 and C.D. was calculated.

3.11 Model calibration and validation

InfoCrop model developed by Division of Environmental Sciences, IARI, New Delhi was used to test and evaluate the experimental treatments through computer program. Model was calibrated by the minor adjustments of some model features to record simulated values by near the witnessed data. The model validation was done to approve that the adjusted model strongly signifies situation of the real life. Model was validated by using weather, soil and crop data of the study location Model was standardized and then RMSE was calculated to test the closeness of real and simulated grain yields.

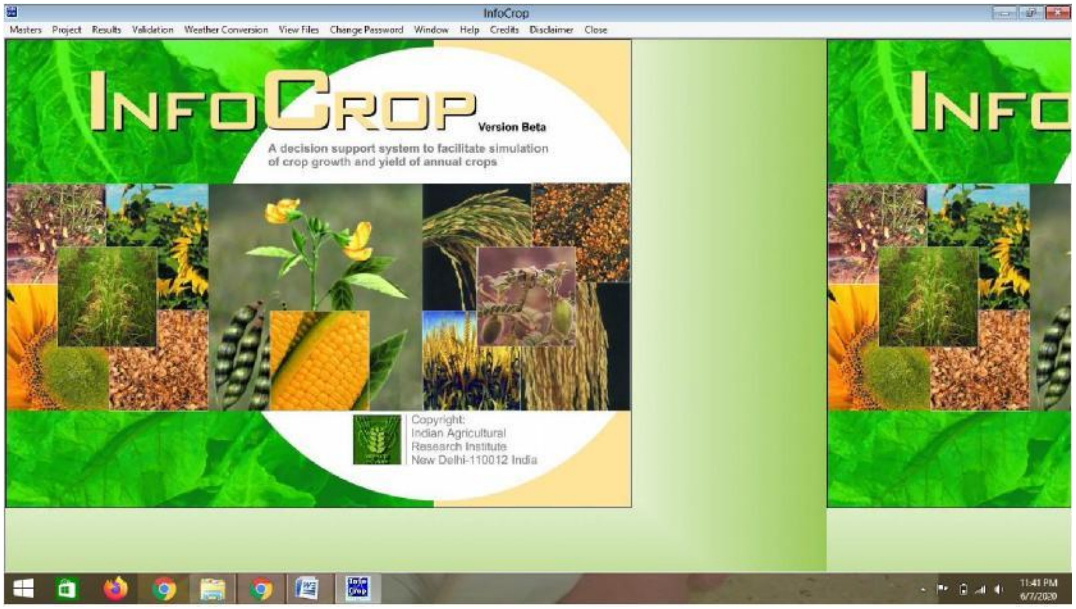


Plate 7: Model used for study

Chapter-IV

RESULTS AND DISCUSSION

Results of the field experiments in wheat crop are presented and discussed here under this chapter.

4.1 Effect of wheat establishment methods, sowing schedules and nitrogen levels on wheat growth and yield

For the ease of discussion, the methods of wheat establishment, sowing schedules and nitrogen doses are termed as M1, M2. M3, D1, D2, D3 and N1, N2 and N3 for, Residue Removal (RR), Residue Incorporation (RI), Residue Burning (RB), 20thNovember, 5th December , 20th December and N @ 50, 75 and 100 kg ha^{-1} respectively. All the growth and yield attributes have been presented in tables & figures and are discussed here under.

4.1.1 Plant height (cm)

During the year 2018-19, a significant increase in plant height was recorded in early stages of crop considering all three aspects of study i.e. establishment method, date of sowing and nitrogen application (Table 2). While considering the establishment method, a clear difference in plant height (up-to 90 DAS) was observed in M3 (residue burning) than M1 (residue removal) and M2 (residue incorporation). Maximum plant height recorded at 30, 60 and 90 DAS i.e. 12.2, 44.2 and 86.3 cm respectively in residue burning method (M3) followed by residue removal (M1) and least plant height was recorded in residue incorporation (M2). The basis for least plant height in residue incorporation method owing to low temperature effect that delayed the emergence and revival of seedlings and raised temperature due to residue burning treatment assisted in early plant growth. These findings are corroborated with Li *et al*., 2008.

Dates of sowing when compared in terms of plant height, maximum plant height was recorded in D1 (20th November) as compared to D2 (5th December) and D3 (20thDecember). This difference in plant height was observed from 30DAS upto harvest.

Table 2. Plant height (cm) of wheat at 30, 60, 90 DAS and at harvest under various treatments during 2018-19

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Wheat Establishment Methods				
Residue Removal (M1)	10.0[a]	42.1 b	83.4[b]	89.4[b]
Residue Incorporation (M2)	9.6[c]	34.8 c	62.3[c]	93.3[a]
Residue Burning (M3)	12.2[a]	44.2 a	86.3[a]	89.2[b]
SED	0.09	0.21	0.21	0.27
Significance	*	*	*	*
Dates of Sowing				
20[th] November (D1)	11.1[a]	41.8[a]	78.3[a]	92.9[a]
5th December (D2)	10.5[b]	40.3[b]	77.2[b]	90.4[b]
20[th] December (D3)	10.1[c]	39.0[c]	76.4[c]	88.7[c]
SED	0.09	0.18	0.13	0.22
Significance	*	*	*	*
Nitrogen Levels				
50% Rec.N (N1)	10.1[c]	39.8[c]	76.5[c]	89.5[c]
75% Rec N (N2)	10.6[b]	40.4[b]	77.5[b]	90.7[b]
100% N (N3)	11.0[a]	40.9[a]	78.1[a]	91.8[a]
SED	0.09	0.18	0.13	0.22
Significance	*	*	*	*
Interaction M X D	*	*	*	*
Interaction M X N	*	NS	*	NS
Interaction D X N	NS	NS	NS	NS
Interaction M X D X N	NS	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Maximum plant height observed after 30 and 60 days of sowing wheat i.e. 11.1 and 41.8 cm respectively in D1 followed by D2 and D3. At 90 DAS maximum plant height to the tune of 78.3 cm at 20[th] Nov. sowing was observed followed by 77.2 and 76.4 cm at 5[th] and 20[th] Dec. sowing of wheat. At harvest stage, trend of plant height remained same with maximum vale 92.9 cm with first date of sowing. It clearly shows that early/timely sowing of wheat crop plays a crucial role in vegetative growth of wheat.

Lesser plant height with delayed sowing and tillage practices was observed by Khan *et al.*, (2015). Similar reports were given by Nazir *et al*., (2005); Haque and Khan (2002); Meelu *et al*., (1994) and Malik (1981) also under different studies.

It reflected from the comparison of the nitrogen doses that extra dose of nitrogen (100% RDN) had a significant impact on plant height. Maximum plant height was recorded in 100% of RDN (upto 90 DAS) i.e. 78.1 cm followed by 75% RDN i.e. 77.5 cm and least was reported into 50% of RDN i.e. 76.5 cm.

Interaction of all three aspects of the study i.e. residue burning (M3), early/timely sowing (D1) and 75% of RDN had a non- significant impact on plant height from initial to final phase of growth, however significant interaction of MXD from 30DAS to harvest stage and MXN at 30DAS and at harvest was noticed significant.

During the second year of study (2019-20) at 30 days after sowing, maximum plant height (11.4 cm) was observed for M3 and it was at par with M2 followed by M1. At 60 days of sowing all methods were at par in producing plant height. However, at 90 DAS and at harvest highest plant height (88.4 and 93.4 cm) was observed in residue management for wheat sowing (Table 3). Dahri *et al*., (2018) also exhibited increased plant height and tiller number by residue incorporation methods. Among all the dates of sowing, first date of sowing (20^{th} November) superseded in plant height at 30, 60, 90 DAS with 11.5 cm , 45.3 cm and 87.2 cm respectively. At harvest highest plant height obtained was 93 cm with sowing on 20^{th} Nov. as compared to sowing on 5^{th} Dec. and 25^{th} Dec. with 90.4 and 88.7 cm of plant heights respectively. 100% RDN showed a significant lead in plant height (10.6, 43.4, 82.3, 91.9 cm) at 30, 60, 90 DAS and at harvest stage respectively than other two nitrogen levels as evident in table 3. Dagash *et al*., (2014) revealed that nitrogen application showed significant positive effect on plant height.

Interaction of all three factors under study had non-significant impact on height of wheat plant over stages. However, interaction between methods and sowing schedules was found significant all stages except at 90DAS.

Table 3. Plant height (cm) of wheat at 30, 60, 90 DAS and at harvest under various treatments during 2019-20

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Wheat Establishment Methods				
Residue Removal (M1)	10.4[b]	43.2[a]	80.1[c]	89.5[b]
Residue Incorporation (M2)	11.2[a]	43.8[a]	88.4[a]	93.4[a]
Residue Burning (M3)	11.4[a]	44.6[a]	85.7[b]	89.3[b]
SED	0.21	0.35	0.44	0.27
Significance	*	*	*	*
Dates of Sowing				
20th November (D1)	11.5[a]	45.3 a	87.2[a]	93.0 [a]
5th December (D2)	10.9[b]	43.6[b]	84.8 a	90.4 [b]
20th December (D3)	10.6[b]	42.7 c	82.3[b]	88.7 [c]
SED	0.12	0.37	0.31	0.22
Significance	*	*	*	*
Nitrogen Levels				
50% Rec.N (N1)	10.6[b]	43.4 b	82.3[c]	89.5 [b]
75% Rec N (N2)	11.0 a	43.8[b]	84.6[b]	90.8 [b]
100% N (N3)	11.3 a	44.5 a	87.3[a]	91.9 [a]
SED	0.12	0.37	0.31	0.22
Significance	*	*	*	*
Interaction M X D	*	*	NS	*
Interaction M X N	NS	NS	NS	NS
Interaction D X N	NS	NS	NS	NS
Interaction M X D X N	NS	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Pooled analysis of two year’s study showed (Table 4) that plant height observed under different methods differ significantly, being highest for residue burning method at 30, 60 and 90 DAS, except at harvest, where residue incorporation method showed highest plant height (91.9 cm).

Table 4. Pooled plant height of wheat at 30, 60, 90 DAS and at harvest under various treatments

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Wheat Establishment Methods				
Residue Removal (M1)	10.2[b]	42.6[b]	81.8[b]	89.2[b]
Residue Incorporation (M2)	10.5[b]	39.3[c]	75.3[c]	91.9[a]
Residue Burning (M3)	11.8[a]	44.4[a]	86.0[a]	88.3[b]
SED	0.09	0.12	0.15	1.33
Significance	*	*	*	*
Dates of Sowing				
20th November (D1)	11.3[a]	43.6[a]	82.8[a]	91.4[a]
5th December (D2)	10.7[b]	42.0[b]	81.0[b]	90.0[a]
20th December (D3)	10.4[b]	40.8[c]	79.4[c]	88.0[b]
SED	0.08	0.18	0.16	1.29
Significance	*	*	*	*
Nitrogen Levels				
50% Rec.N (N1)	10.4[b]	41.6[c]	79.4 c	88.7[a]
75% Rec N (N2)	10.8[a]	42.1[b]	81.0 b	89.0[a]
100% N (N3)	11.1[a]	42.8[a]	82.7 a	91.7[a]
SED	0.08	0.18	0.16	1.29
Significance	*	*	*	*
Interaction M X D	*	*	NS	NS
Interaction M X N	*	NS	NS	NS
Interaction D X N	NS	NS	NS	NS
Interaction M X D X N	NS	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

However, among dates of sowing for 30, 60, 90 DAS and at harvest maximum plant height was observed under first date of sowing i.e. 20th November followed by D2 and D3. At harvest stage both D1 and D2 were at par followed by D3. This shows that delayed sowing by 5th December would not differ in plant height at later stage of crop growth. At harvest stage, pooled plant height showed non- significant difference among all the dates of sowing.

While considering the effect of different nitrogen levels on plant height, no significant difference in plant height was noticed among treatments at harvest stage, though plant height remained significant in earlier stages of plant growth and at recommended level of nitrogen, more plant height was observed i.e. plant height at 100% RDN was to the tune of 11.1, 42.8, 82.7 and 91.7 cm followed by 75% RDN and lastly at 50% RDN.

Interaction among all the three factors was observed non-significant in terms of plant height. The possible reasons for non-significant difference in plant height at harvest may be that assimilates are utilized by the plants towards increasing reproductive growth at this time as proved by Islam *et al*., (2013) by observing negative relationship between plant height and grain yield.

4.1.2 Number of tillers plant^{-1}

During 2018-19, number of tillers per plant at 30 DAS were maximum (26.9) for residue burning (M3) followed by residue removal (M1) and residue incorporation (M2) methods as presented in table 5. There is remarkable difference in tillers per plant observed in three methods. Maximum tillers in residue burning method might be owing to fast growth of tillers and their lesser mortality affected by congenial temperature conditions provided by residue burning, as generally there is occurrence of frost and very low minimum temperature faced by wheat during this period. As presented in fig 2(b) that minimum temperature was lowest coincided with tillers formation for first date of sowing.

When the second aspect of study is considered for tillers per plant, it is noted that first and second dates of sowing were at par statistically in terms of tiller number followed by D3 (20th December) may be due to shorter time period for growth due to late sowing coincided with low temperature at seedling stage also corroborated with the observations by Thiry *et al*., (2002), who suggested optimum period of wheat sowing increased tillering in wheat.

Table 5. Number of tillers per plant in wheat at 30 and 60 DAS during 2018-19

Treatments	**30 DAS**	**60 DAS**
Wheat Establishment Methods		
Residue Removal (M1)	24.5^{b}	23.1^{b}
Residue Incorporation (M2)	24.8^{b}	22.9^{b}
Residue Burning (M3)	26.9^{a}	26.3^{a}
SED	0.15	0.27
Significance	*	*
Dates of Sowing		
20th November (D1)	26.7^{a}	25.4^{a}
5th December (D2)	25.2^{a}	24.3^{a}
20th December (D3)	24.3^{b}	22.7^{b}
SED	0.26	0.32
Significance	*	*
Nitrogen Levels		
50% Rec.N (N1)	25.0^{b}	23.4^{b}
75% Rec N (N2)	25.6^{a}	23.9^{b}
100% N (N3)	25.6^{a}	25.2^{a}
SED	0.26	0.32
Significance	*	*
Interaction M X D	*	NS
Interaction M X N	NS	*
Interaction D X N	NS	NS
Interaction M X D X N	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing; N=Nitrogen levels and SED=Standard error of difference.

However no difference in tillers count (25.6) found for 75% and 100% RDN. Statistically identical tillers per plant were also reported by the applications of 80 to 120 kg N ha^{-1} (Shirazi *et al*., 2014).

Similar trend of tiller count was observed at 60DAS also for methods and sowing schedules; however as the N level is concerned, highest number of tillers were 25.2 followed with recommended dose of nitrogen.

In all the treatments number of tillers noticed at 60 DAS was lesser although very less difference was there, may be due to any biotic or abiotic stress faced by plants. In present case, the reason for lesser number of tillers at 60 DAS may be due to heavy rainfall, water logging and termite attack or high yielding variety. Tiller mortality and tiller survival by showing their association with abiotic and biotic factors in different experiments was justified by Engledow (1925); Smith (1933) ; Rawson (1967) ; Bunting and Drennan (1965) ; Barley and Naidu (1964) and Syme (1967). Johnston and Fowler (1992) observed relationship of tillers death with drought condition. However, Duggan *et al*., 2000 revealed that the tiller die back due to reduced ability of high yielding genotype to tolerate adverse weather conditions.

All the interactions observed among factors w.r.t tiller number were non-significant except MXD at 30DAS. While significant interaction was showed between methods and N levels at 60DAS.

After 30 and 60 days of sowing during 2019-20, maximum tillers (24.1 & 24.8) respectively were observed under residue incorporation (M2) followed by burning and removal plots (Table 6). The difference in tiller number was statistically significant among the methods. Highest number of tillers in residue inclusion owing to more available N to plants due to more decomposition of residues in the soil during second year of study was also reported (Maskina *et al*., 1988).

Among dates of sowing, sowing done at 20th November (D1) formed highest number of tillers during 30 and 60 DAS @ 23.7 and 22.3 respectively. Late sowing resulted in lower tiller count was also registered by Ansari *et al*., (1989) and Tahir *et al*., (2009) may be due to low temperature injury to plants.

Early sowing resulted in vigorous growth with larger leaf and more tiller number has also been justified by Munir *et al*.,(2002) and Tanveer *et al*., (2003). Here also relationship among all the three factors was non-significant; interaction of sowing date with methods and nitrogen levels was significant at 60DAS.

Different nitrogen levels showed at par numbers of tillers at 30 DAS with 50% and 75% RDN, however maximum number noticed in 100% RDN. At 60 DAS highest tiller count (22.3) was noted in plots applied by 100% RDN and followed by 75 and 50% RDN. The difference of tiller number between two years may be due to harsh winter conditions during second year that caused slow tillering or more mortality (Bulman and Hunt, 1988).

Table 7 presented the tiller number over two years of study. It is evident that M3 and M2 methods showed higher number of tillers which are statistically at par also for 30 and 60 DAS followed by removal of residue method. Verma and Pandey (2013) and Malik *et al*., (1981) found higher number of tillers with incorporation of crop residue.

Table 6. Number of tillers per plant in wheat at 30 and 60 DAS during 2019-20

Treatments	**30 DAS**	**60 DAS**
Wheat Establishment Methods		
Residue Removal (M1)	20.7^{c}	19.0^{c}
Residue Incorporation (M2)	24.1^{a}	24.8^{a}
Residue Burning (M3)	22.5^{b}	21.3 ^{b}
SED	0.24	0.13
Significance	*	*
Dates of Sowing		
20th November (D1)	23.7^{a}	22.3^{a}
5$_{th}$ December (D2)	22.5^{b}	21.9^{a}
20th December (D3)	21.1^{c}	21.0^{b}
SED	0.22	0.16
Significance	*	*
Nitrogen Levels		
50% Rec.N (N1)	22.1^{b}	20.9 ^{c}
75% Rec N (N2)	22.4^{b}	21.9^{b}

100% N (N3)	22.9[a]	22.3[a]
SED	0.22	0.16
Significance	*	*
Interaction M X D	NS	*
Interaction M X N	NS	*
Interaction D X N	NS	NS
Interaction M X D X N	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference, figure in parentheses are CD values.

Table 7. Pooled tiller count per plant in wheat at 30 and 60 DAS

Treatments	**30 DAS**	**60 DAS**
Wheat Establishment Methods		
Residue Removal (M1)	22.6[b]	21.1[b]
Residue Incorporation (M2)	24.5 a	23.9[a]
Residue Burning (M3)	24.7[a]	23.8[a]
SED	0.14	0.16
Significance	*	*
Dates of Sowing		
20th November (D1)	25.2 a	23.9 [a]
5th December (D2)	23.9 b	23.1 [b]
20th December (D3)	22.8[c]	21.9 [c]
SED	0.19	0.17
Significance	*	*
Nitrogen Levels		
50% Rec.N (N1)	23.6[b]	22.1 [c]
75% Rec N (N2)	24.0[a]	22.9[b]
100% N (N3)	24.3[a]	23.8[a]
SED	0.19	0.17
Significance	*	*
Interaction M X D	*	NS
Interaction M X N	NS	*
Interaction D X N	NS	NS
Interaction M X D X N	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

With respect to dates, maximum tillers were found in 20th Nov. sowing followed by 5th Dec and 20th Dec. sown wheat at 30 and 60 DAS. Maximum tiller count was 25.2 followed by 23.9 and 22.8 in 30 DAS. The values are 23.9 followed by 23.1 and 21.9 after 60 days of sowing in wheat.

When N levels were compared in terms of producing tiller numbers, no significant difference was at 30 DAS among two nitrogen application levels that are 75% RDN and 100% recommended. However after 60 days of sowing, at 100% RDN maximum tillers (23.8) were observed followed by other two levels. With increased N rate, tiller density increased was also observed in wheat by Otteson *et al*., (2008). All interactions were non-significant for tiller count except methods of sowing with nitrogen levels at 60 DAS and MXD at 30 DAS.

4.1.3 Effective tillers plant^{-1}

Effective tillers per plant observed during 2018-19 and 2019-20 were maximum under residue incorporation treatment to the tune of 20.5 and 17.7 respectively. Average number of effective tillers during both years was also highest (19.1) for M2 followed by residue burning (M3) and removal (M1) (Table 8). Largest spike number, grain number in each spike, grain number, seed index with higher residue was also reported by Sadeghi and Bahrani (2009) in Iran and Asseng *et al.*, (1998) may be due to more availability of nutrients by incorporation relative to removal and burning that causes loss of almost all major nutrients in soil.

Among sowing schedules, sowing of wheat done on time has given largest effective tillers count per plant (19.1 and 15.3) during 2018-19 and 2019-2020 compared to delayed sowing by 15 and 30 days may be caused by more time for crop to photosynthesize the food due to longer vegetative phase compared to late sown plants. It is also justified by the findings of Alam *et al*., (2013) with significantly higher tiller count, spike number, and grain yield by earlier wheat sowing.

Table 8. Number of effective tillers per plant in wheat at harvest

Treatments	**2018-19**	**2019-20**	**Mean (18-19 & 19-20)**
Wheat Establishment Methods			
Residue Removal (M1)	17.6[c]	13.6[c]	15.6[c]
Residue Incorporation (M2)	20.5[a]	17.7[a]	19.1[a]
Residue Burning (M3)	19.1[b]	14.5[b]	16.8[b]
SED	0.17	0.16	0.13
Significance	*	*	*
Dates of Sowing			
20th November (D1)	20.1[a]	16.7[a]	18.4[a]
5th December (D2)	19.1[b]	15.3[b]	17.2[b]
20th December (D3)	18.0[c]	13.8[c]	16.0[c]
SED	0.15	0.17	0.12
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	18.0[c]	15.0 [b]	16.5 [c]
75% Rec N (N2)	19.1[b]	15.7[a]	17.4[b]
100% N (N3)	20.2[a]	15.1[b]	17.7 [a]
SED	0.15	0.17	0.12
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	*	NS	NS
Interaction D X N	NS	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference. Values in parentheses are CD values.

Nitrogen application levels caused variation in effective tillers count with recommended dose compared to 75% and 50 % RDN during 2018-19. Largest effective tiller number (20.2) in N3 followed by 19.1 and 18 were observed respectively for N2 and N1. During 2019-20 also similar trend was observed for N levels, highest being 17.7 followed by 17.4 and 16.5 respectively for N3, N2, and N1. Recommended nitrogen produced highest number of effective tillers during study periods might influenced good vegetative growth.

Interaction between methods and dates of sowing presented in fig 3 for effective tillers plant^{-1} showed that sowing crop on first or second dates viz. 20th November and 5$_{th}$ December with residue incorporation method would produce maximum effective tillers per plant also significantly higher from other methods during 2018-19.

On similar note, interaction of MXN was observed for 2018-19 in terms of effective tillers per plant as given in fig 4. In this, 75% N showed an increase to the tune of 6.8% by an increment of 25% when compared with 50% N however with further incremental nitrogen only 5.5% increase in tiller number was seen with incorporation of residue method. In M3 (Residue burning), increased N level from 75 to 100% registered only 3% increment in effective tiller number per plant, however M1 observed about 8% increase in effective tillers with 25% N increase from 75% N. These results are in agreement with Sadhegi and Bahrani (2009); Garrido Lestache *et al.*, (2005) and Lopez-Bellido *et al.*, (1996).

Both years resembled w.r.t interaction between methods and sowing schedules. During 2019-20, largest effective tiller number (19.5) was observed with the interactive effect of methods and sowing schedules in the combination of M2 D1 as evident in fig 5 followed by M2D2 and M2D3 with 17.8 and 15.8 tillers per plant. In other two methods trend was similar with least difference in all sowing dates, though number was lesser than M2. More number of effective tillers may be caused by more time for crop to photosynthesize the food due to longer vegetative phase compared to late sown plants. It is also justified by the findings of Alam *et al.*, (2013) with significantly higher tiller count, spike number, and grain yield by earlier wheat sowing.

Mean or pooled effective tillers per plant showed highest value i.e. 19.1 in M2 followed by M3 and M1 with 16.8 and 15.6 effective tillers per plant. Highest number of effective tillers was 18.4 under first date of sowing, however lesser number for D2 and D3 was observed to the tune of 17.2 and 16 respectively.

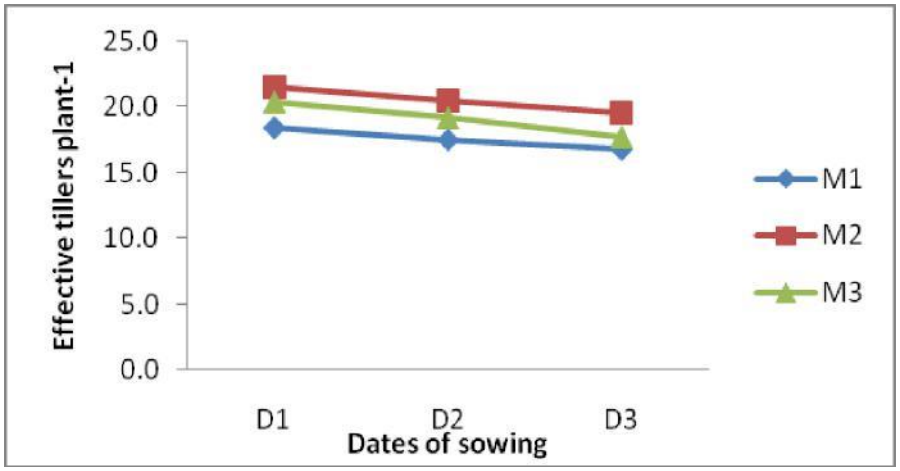


Fig 3. Effect of interaction of methods with sowing dates on effective tillers plant^{-1} during 2018-19

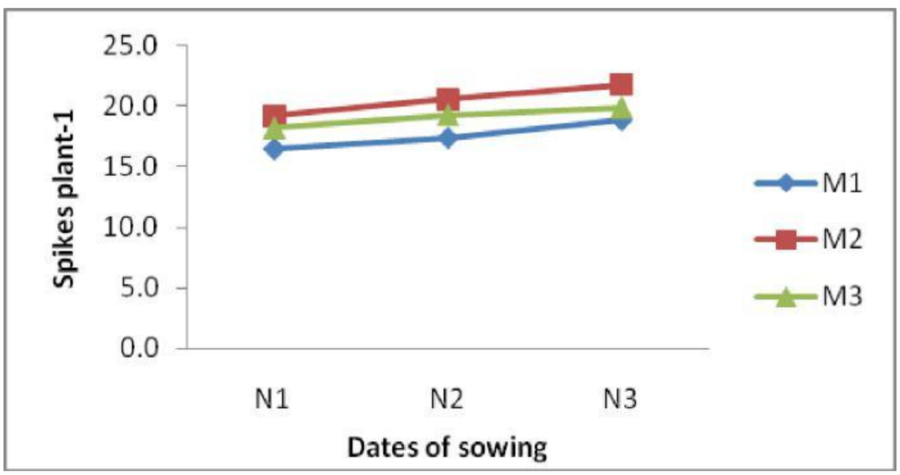


Fig 4. Effect of interaction of methods with N levels on effective tillers plant^{-1} during 2018-19

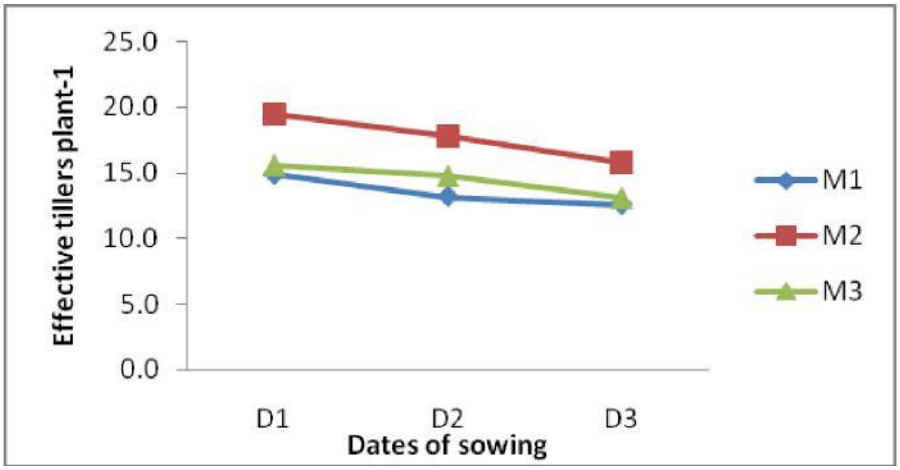


Fig 5 . Effect of interaction of methods with dates of sowing on effective tillers plant^{-1} during 2019-20

Recommended dose of nitrogen caused statistically higher spike number i.e. 17.7 followed by 17.4 and 16.5 for N2 and N1 respectively. All the interactions were non-significant except methods and sowing dates. As presented in fig 6 maximum spikes per plant was for M2D1 (20.5) followed by M2D2 (19.2) and M3D1 (18.0) and least spike number was observed for M1D3.

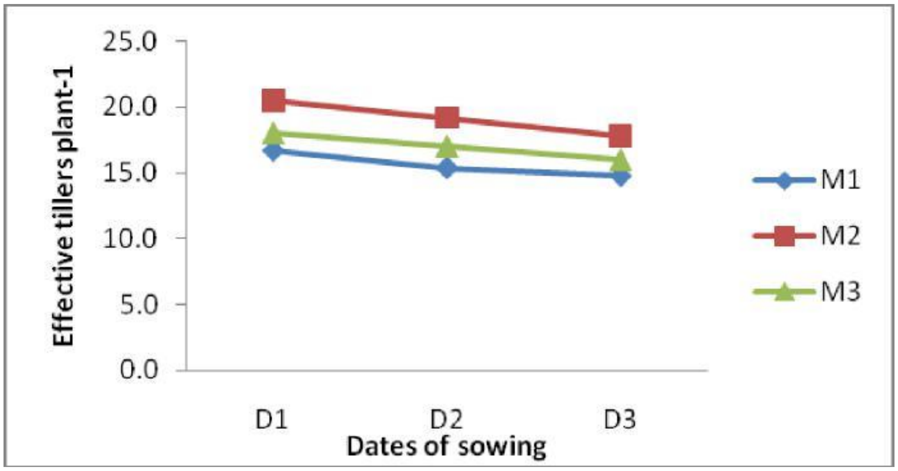


Fig 6. Effect of interaction of methods with dates of sowing on effective tillers plant^{-1} for both years (average)

4.1.4 Spike length (cm)

During 2018-19, maximum length of spike (10.3 cm) in wheat plant was observed for residue removal treatment (M1) though significantly not different from other two methods (Table 9). However, highest spike length (12.1 cm) was attained in residue incorporation method of wheat establishment followed by M3 and M1 during second year of study i.e. 2019-20.

Table 9. Spike length (cm) in wheat at harvest

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	10.3	10.0[c]	10.2[b]
Residue Incorporation (M2)	10.0	12.1[a]	11.1[a]
Residue Burning (M3)	9.9	10.4[b]	10.2[b]
SED	0.20	0.08	0.09
Significance	NS	*	*
Dates of Sowing			
20th November (D1)	10.9[a]	11.3[a]	11.1[a]
5th December (D2)	10.2[b]	10.9[b]	10.6[b]
20th December (D3)	9.2[c]	10.3[c]	9.8[c]
SED	0.15	0.11	0.11
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	10.1	10.4[c]	10.3[b]
75% Rec N (N2)	10.2	10.9 b	10.6[a]
100% N (N3)	10.0	11.2[a]	10.6[a]
SED	0.15	0.11	0.11
Significance	NS	*	*
Interaction M X D	NS	*	*
Interaction M X N	*	NS	NS
Interaction D X N	NS	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Pooled analysis also showed the similar result with 11.1 cm spike length in M2 statistically higher than other two methods may be due to more availability and utilization of nutrients due to decomposition of residue present in the soil during second cropping year. Higher spike length was also reported by Feizabady (2013) in wheat when residue of previous crop was incorporated before sowing.

Among dates of sowing, timely sowing (20th November) showed superiority in spike length during 2018-19 and 2019-20 with a mean value of 11.1 cm higher than other two dates of sowing. Maximum spike length achieved by early sowing may be due to higher photosynthesis rate, more production of assimilates and translocation of nutrients from source to sink as the crop gets more time for vegetative growth compared to delayed wheat sowing.

By comparing the effect of different N levels on spike length, it has been observed that no significant difference is there among levels of N during 2018-19, but for the next year (2019-20) with 100% N application more spike length obtained may be due to residue incorporation effect. These results are in line with the findings of Verma and Pandey (2013), by observing maximum spike length with additional dose of NPK in wheat crop. However, for pooled spike length, residue incorporation, first date of sowing and recommended N produced highest spike length in wheat. These results are corroborated with the work of Iqbal *et al*., 2012 who advocated that all the growth and yield factors were the maximum at nitrogen @ 125 kg ha^{-1} and were lowest without nitrogen

During 2018-19, maximum length of spike (10.7 cm) in wheat plant was observed for residue removal method with 75% N (Fig 7) and least in M3N3 that means with residue burning more dose of nitrogen has no effect on spike length. In M2 with increasing N doses, spike length increased though increase noticed was very less.

Highest spike length (13 cm) followed by 12.5 and 10.9 cm respectively for M2D1, M2D2 and M2D3 was observed (Fig 8) during 2019-20. Lowest spike length was observed in M1 for all the sowing schedules. Highest spike length also observed in 100% N compared to 75% and 50%.

Pooled analysis also showed the similar interaction for spike length; highest for M2D1 (11.9 cm) higher than other two methods may be owing to increased availability and consumption of nutrients through decomposition of residue present in the soil during second cropping year (Fig 9). All other interactions were observed non-significant.

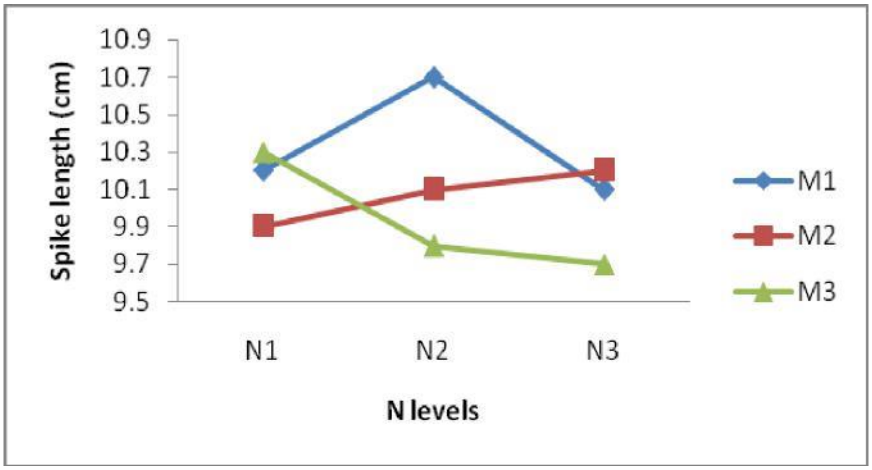


Fig 7. Interactive effect of methods and N levels on spike length in wheat for 2018-19

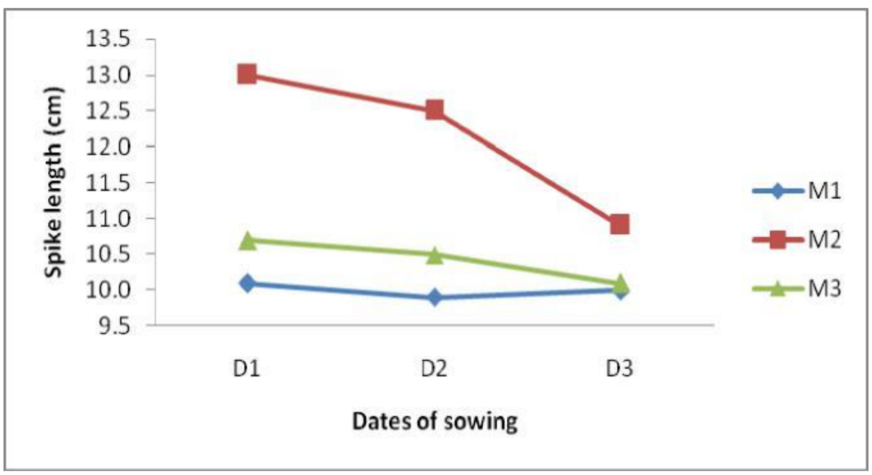


Fig 8. Interactive effect of methods and sowing dates on spike length in wheat for 2019-20

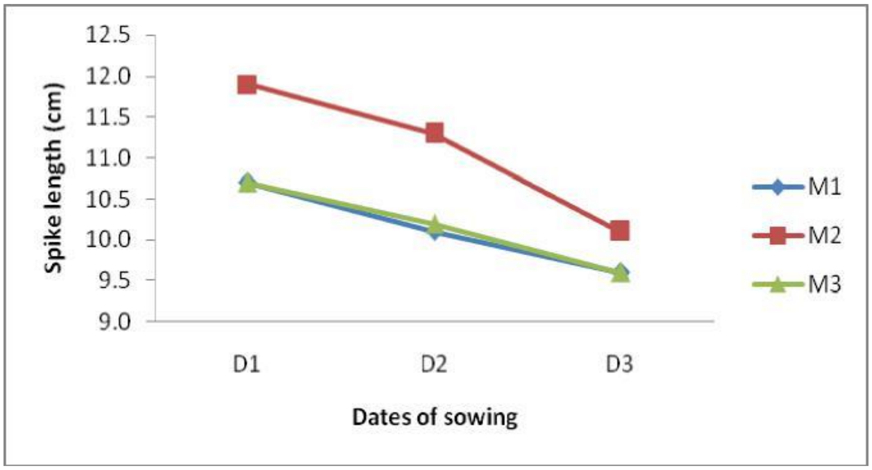


Fig 9. Interactive effect of methods and sowing dates on spike length in wheat for pooled data

4.1.5 Number of grains spike^{-1}

Highest number of grains per spike (49.4) followed by 47.2 and 43.3 for M3, M1 and M2 respectively were observed during 2018-19 (Table 10).

During 2019-20, almost 18 % lesser number of grains from the previous year per spike for residue burning (M3) and 12% reduced number for residue incorporation was recorded. Pooled data of two years showed maximum grains to the tune of 43.7 per spike in M3 (Residue burning) followed by statistically at par with incorporation and removal methods. Lesser number of grains per spike during 2019-20 may be due to lowering of minimum temperature during vegetative phase from end of December month to mid-February and rising maximum temperature at grain filling stage of crop. Heat stress based declining grain number per spike was also indicated by Saini *et al*., (1982) and Jaiswal *et al*., (2017).

Table 10. Number of grains per spike in wheat at harvest

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	47.2^{b}	37.5^{c}	42.3^{b}
Residue Incorporation (M2)	43.3^{c}	38.1^{b}	42.0^{b}
Residue Burning (M3)	49.4^{a}	40.7^{a}	43.7^{a}
SED	0.11	0.10	0.09
Significance	*	*	*
Dates of Sowing			
20th November (D1)	50.5^{a}	41.2 a	45.9^{a}
5$_{th}$ December (D2)	46.2^{b}	39.0 b	42.6^{b}
20th December (D3)	43.2^{c}	36.0 c	39.6^{c}
SED	0.28	0.25	0.18
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	45.2^{c}	37.9 b	41.5^{c}
75% Rec N (N2)	46.5^{b}	39.0 a	42.8^{b}
100% N (N3)	48.2^{a}	39.4 a	43.8^{a}
SED	0.28	0.25	0.18
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	NS	*	NS
Interaction D X N	NS	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Among three dates of sowing, sowing done on first date (20th Nov.) produced significantly higher number of grains (50.5 & 41.2) respectively for both years of study than other two sowing dates. For average number of grains in a spike the trend remained the same, though highest number (45.9) were in D1 followed by D2 and D3 with 42.6 and 39.6 number of grains respectively was observed. Least grains count per spike with late sowing in wheat revealed by Jaiswal *et al*., (2017).

For 2018-19, treatment applied with recommended dose of N produced notably more number of grains (48.2) than other two levels. During 2019-20 same results were observed with 39.4, 39 and 37.9 grains in a spike at 100, 75 and 50% RDN. Singh *et al*., (2005) noticed same observations with additional dose of urea during initial years of residue incorporation caused an increase in grain count in the succeeding years with recommended dose also might be due to better source size that contributed towards sink. For pooled data, highest number of grains per spike (43.7) due to residue burning, 45.9 due to first sowing date and 43.8 because of higher N dose was observed.

As the interaction between methods and sowing dates is significant in terms of grains per spike, so it is shown in fig10 that by the first method of sowing (M1) done on 20th November, largest number of grains per spike (53.8) obtained, thereafter about 14 and then 10% decline was observed by delayed sowing up-to 15 and 30 days than timely sowing. Least number of grains was obtained by the combination of residue incorporation and 20th December sowing, however it was at par with M1D3. One noteworthy finding here is that by sowing through residue inclusion on any of the dates showed least variation i.e. 5% and 3% respectively in M2D2 and M2D compared to M1D1. All other interactions were found non-significant.

During 2019-20, reduction in grains per spike was observed for M2D1N2 (6%) and highest for M1D1N3 (26%) as compared to 2018-19 might be owing to favourable weather conditions at reproductive stage.

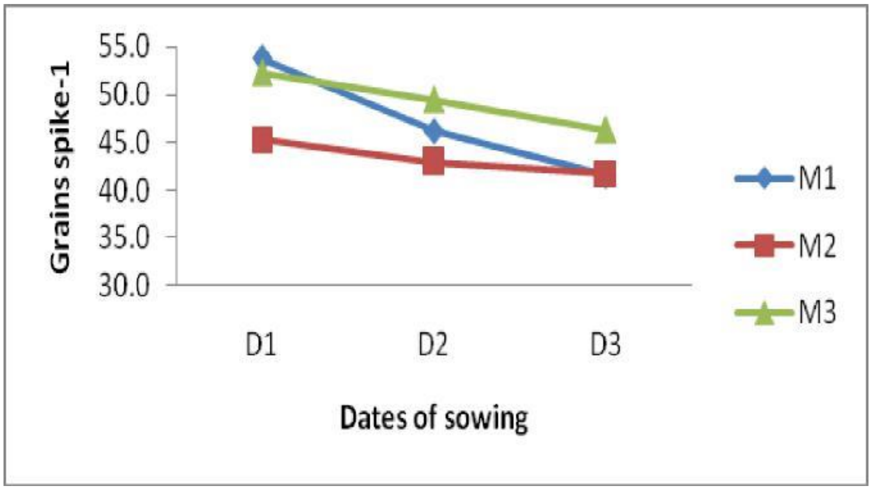


Fig 10.Interactive effect of methods and sowing dates on grains spike-1 during 2018-19

Significant relationship in methods with sowing dates and N levels was observed for grain number per spike (Fig11&12) during 2019-20. Almost similar number of grains was obtained in M1D1, M2D1 and M3D1, while as the sowing delayed M3D2 and M3D3 took a lead followed by M1D2. The noticeable point here is that if sowing is delayed upto one month combined with removal of residue method, grain number can be least of all treatment combinations.

As presented in fig 12 , it has been observed that with increasing N level increase in grains per spike was there although small, while in M1 and M3 applied with all N levels, almost negligible grain increase was noticed. These results might be due to slow response of crop to nitrogen levels.

Interaction of methods with dates of sowing is presented in fig 13. Maximum grains in a spike (47.0) observed with the interaction of D1 , M3 and M1 followed by M2D1.Therafter decline was observed by delaying in sowing of crop from D1 to D2 and D3 in M1 and M3 methods. The important observation here is that by the combination of M2 with D2 and D3 although decline in grains takes place but this decline is much less than other methods.

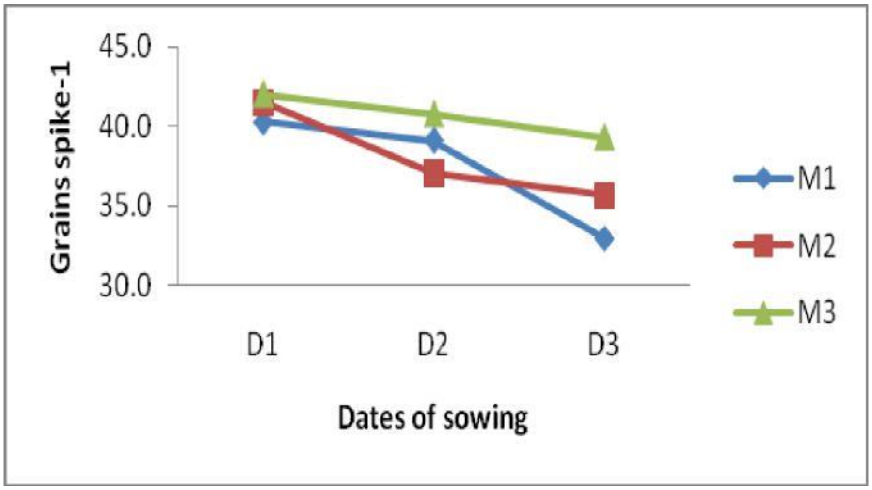


Fig 11. Interactive effect of methods and sowing dates on grains spike-1 during 2019-20

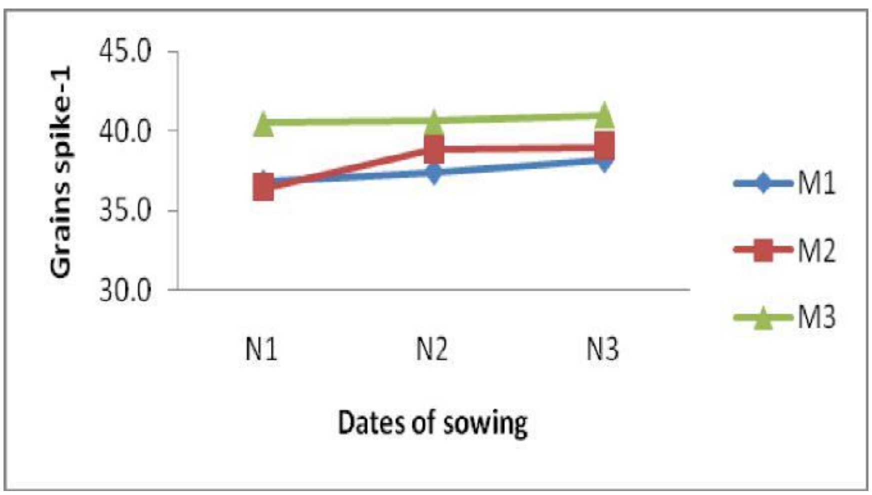


Fig 12. Interactive effect of methods and N levels on grains spike-^{1} during 2019-20

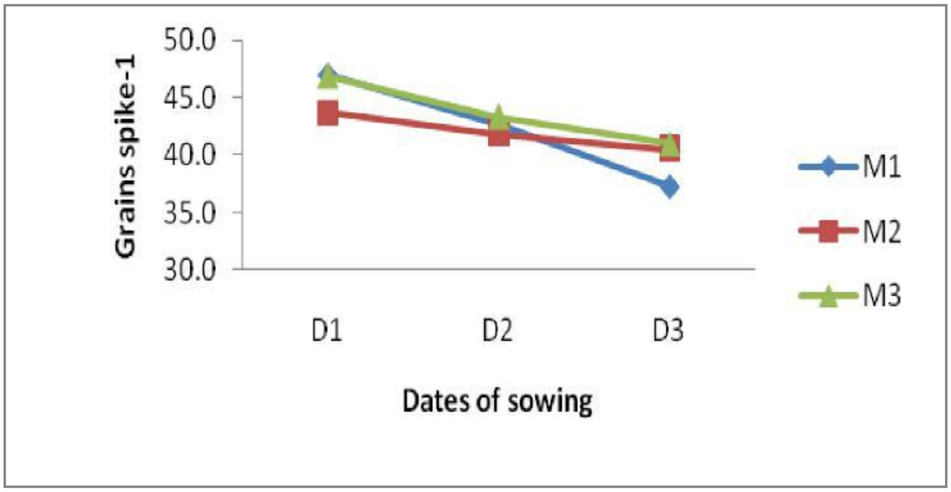


Fig 13. Interactive effect of methods and sowing dates on grains spike^{-1} during both years (mean)

4.1.6 1000 grain weight (g)

By comparing aspect of methods in terms of seed index (1000- grain weight), statistically higher 1000- grain weight (33.3 g) was observed under residue incorporation method (M3) followed by residue removal and burning with 32.8 and 31.4 g seed indices respectively during 2018-19. Li *et al*., (2008) showed that irrigation and straw mulching elevated the grain count, but no noticeable effects were observed for 1000-kernel weight.

During the second year of study, trend followed by seed index was similar to first year being statistically higher for M2 with 31.1 g seed index followed by residue removal (Table 11). Lesser 1000-grain weight was observed under all the methods in 2019-20 than 2018-19 to the tune of about 6% decline for M1 and 7% for M2 methods, but 4% decline in residue burning method. The reason might be more moisture and cloudiness during 2019-20 at reproductive stage of crop. Nedeva and Nicolova (1999) indicated that less moisture and increased dry matter post- flowering and at grain filling of wheat, increased seed index and germination percent.

Table 11. 1000-grain weight (g) in wheat at harvest

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	32.8^{b}	30.6^{b}	31.7^{b}
Residue Incorporation (M2)	33.3^{a}	31.1^{a}	32.2^{a}
Residue Burning (M3)	31.4^{c}	30.3^{c}	30.8^{c}
SED	0.32	0.16	0.10
Significance	*	*	*
Dates of Sowing			
20^{th} November (D1)	34.7^{a}	32.6_{a}	33.7^{a}
5_{th} December (D2)	32.4_{b}	31.0_{b}	31.8^{b}
20^{th} December (D3)	30.1_{c}	28.4_{c}	29.4^{c}
SED	0.22	0.28	0.20
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	31.8^{c}	29.8^{b}	33.1^{c}
75% Rec N (N2)	32.6^{b}	30.8_{a}	33.9^{b}
100% N (N3)	33.1^{a}	31.4^{a}	34.5^{a}
SED	0.22	0.28	0.20
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	*	NS	NS
Interaction D X N	*	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Among different dates of sowing, sowing of wheat done on first date superseded during both years of study by producing 34.7 and 32.6 g seed index for 2018-19 and 2019-20 respectively. Seed index ranged from 30.1 – 34.7 g in 2018-19 and 28.4-32.6 g during 2019-20. Mean of two years however showed a change in seed index ranged from 29.4-33.7 g least for D3 and highest for D1. Dagash *et al*., (2014) also revealed that the early sown wheat showed more 1000-seed weight and harvest index. The reason for this may be relation of longer duration with higher vegetative growth and larger source size.

While comparing different N levels, it has been noticed that 1000- grain weight during 2018-19 was remarkably influenced by nitrogen levels, highest (33.1 g) with 100% RDN followed by 32.6 and 31.8 g for 75% and 50% respectively. During 2019-20, 75% and 100% N levels were at par statistically in producing 1000- grain weight. Average of two years' study showed significantly higher seed index (34.5 g) for N3 levels.

Interactions between methods and sowing dates during 2018-19 showed significantly higher seed index in D1 as compared to other two sowing dates that means by residue incorporation and timely sowing heavier grains can be obtained (Fig 14). Interaction of methods and N levels showed that first method (M1) and third method with 100% exceeded in producing higher seed index (Fig 15). Interaction of sowing dates with N levels justify the need of timely sowing with 100% N level for more seed index, but with delayed sowing 75% level behaves almost similarly like 100% N (Fig 16).

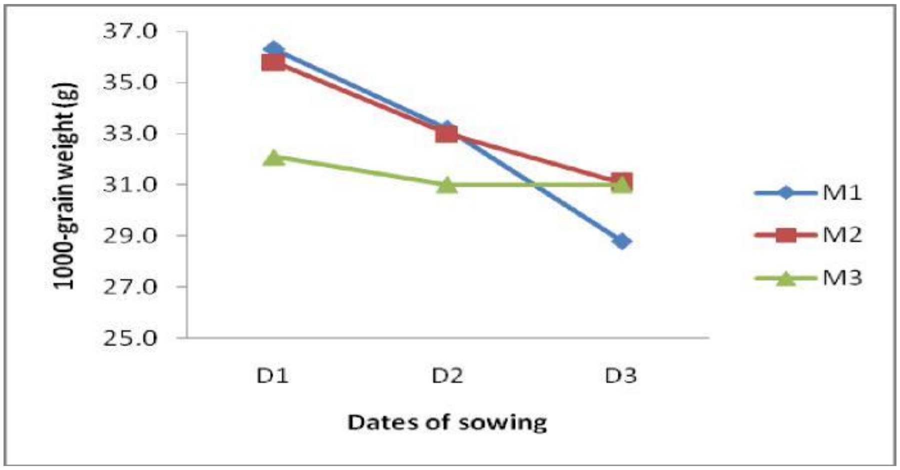


Fig 14. Interactive effect of methods and sowing dates on 1000-grain weight during 2018-19

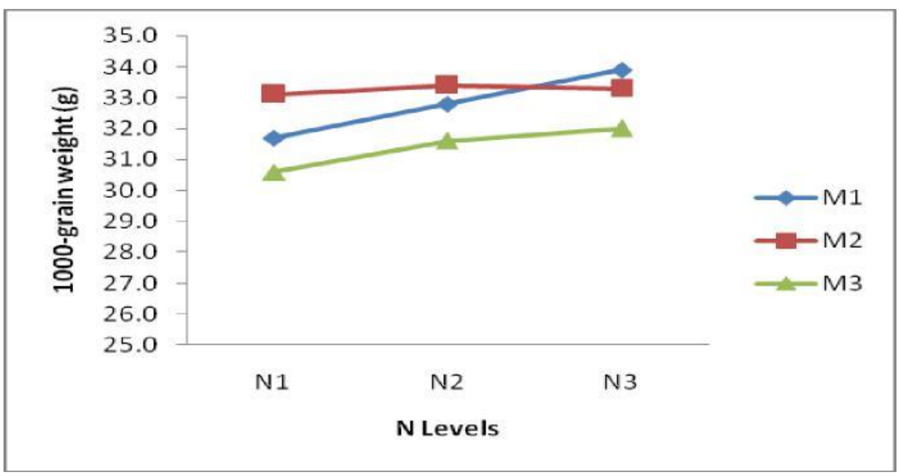


Fig 15. Interactive effect of methods and N levels on 1000-grain weight during 2018-19

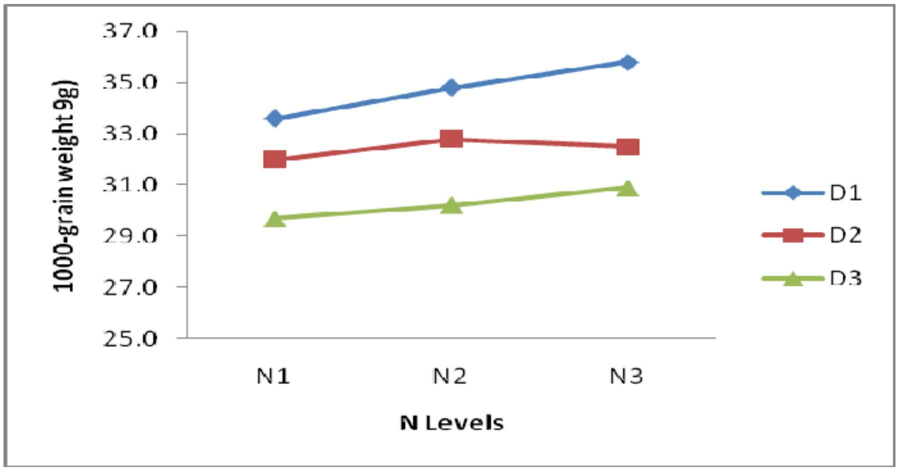


Fig 16. Interactive effect of sowing dates and N levels on 1000-grain weight during 2018-19

During 2019-20, non–significant interactions were noticed except MXD. Non-significant interaction among all of the three variables (MXDXN) for mean seed index of two years and in methods with N levels. However, sowing dates interacted with methods as well as N levels to give 1000-grain weight. Interaction shows (Fig17) that residue incorporation at first date of sowing produced highest seed index. M1 and M2 responded in the same fashion to sowing schedules compared to M3 with lesser seed index for pooled data (Fig 18). Highest pooled seed index was observed in combinations of N levels and sowing dates. With each delay though seed index declined but with increasing nitrogen dose, it increased (Fig19).

On the contrary, Bellido *et al*., (2000) reported inversely proportional relationship between seed weight and nitrogen doses may be due to higher per spike grain number lesser 1000-grain weight driven by enhanced nitrogen application rates.

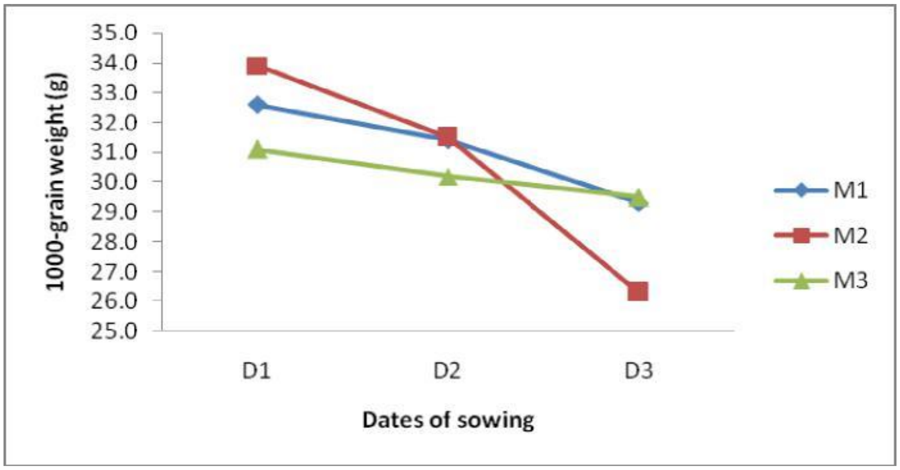


Fig 17. Interactive effect of methods and sowing dates on 1000-grain weight during 2019-20

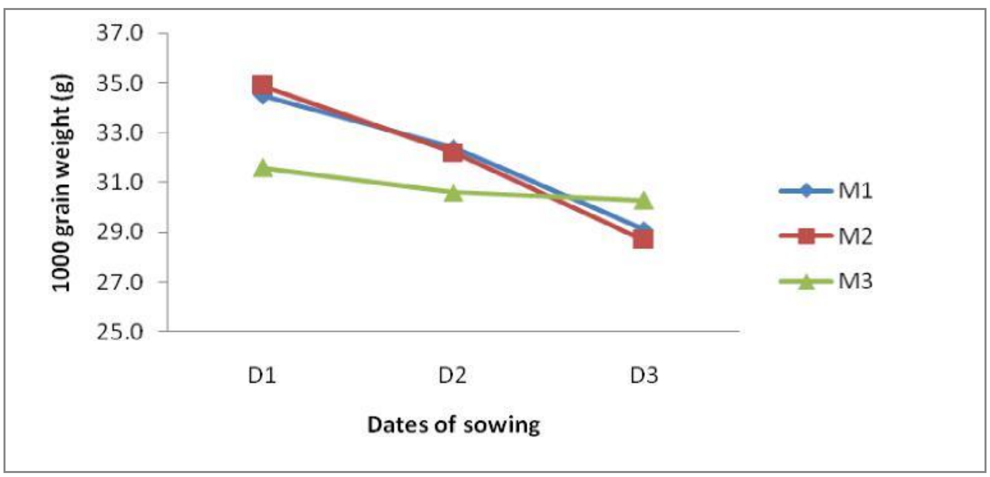


Fig 18. Interaction of methods and sowing dates in pooled 1000-grain weight

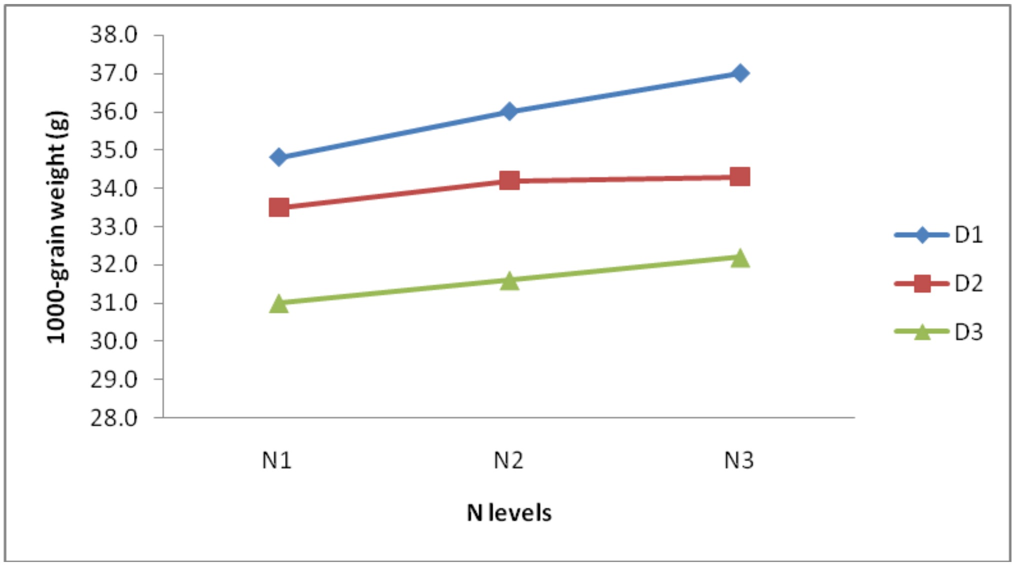


Fig 19. Interaction of sowing dates and N levels in pooled 1000-grain weight

4.1.7 Grain yield (t ha^{-1})

During first year of study (2018-19), highest grain yield (5.7 t ha^{-1}) found in residue incorporation method (M2) of wheat establishment, which was at par with residue removal method (M1) having similar grain yield followed by residue burning method with grain yield of 5.4 t ha^{-1} (Table 12). During 2019-20, statistically higher yield (5.3 t ha^{-1}) was obtained under M2 method followed by M3 and residue incorporation (M1) though lesser than 2018-19. Trend was alike in mean grain yield highest (5.5 t ha^{-1}) for M2 followed by 5.4 and 5.3 t ha^{-1} for M1 and M3. The reason may be that grain yield is the overall effect of vegetative and reproductive growth of plants under varied environmental and management conditions, although residue burning method produced highest number of grains, but incorporation of residue gave highest effective tillers per plant and heavier grains with more weight so the grain yield, similar results were given by Brar and Walia (2008). These results are corroborated with findings of Singh *et al*., (2005); Bijay-Singh *et al*., (2008) and Gupta *et al*., (2007) by finding that application of rice residue for short term showed a meager effect on wheat yields but the influence could be observed in 4th year of residues incorporation.

Table 12. Grain yield (t ha^{-1}) in wheat for different treatments

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	5.7 a	5.1 b	5.4^{b}
Residue Incorporation (M2)	5.7 a	5.3 a	5.5^{a}
Residue Burning (M3)	5.4 b	5.1 b	5.3^{b}
SED	0.04	0.02	0.03
Significance	*	*	*
Dates of Sowing			
20th November (D1)	5.9 a	5.5 a	5.7 ^{a}
5$_{th}$ December (D2)	5.6 b	5.3 b	5.4 ^{b}
20th December (D3)	5.3 c	4.7 c	5.2^{c}
SED	0.06	0.03	0.04
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	5.5 c	5.0 b	5.3 ^{c}
75% Rec N (N2)	5.6^{b}	5.2 a	5.4^{b}
100% N (N3)	5.7^{a}	5.3 a	5.6 ^{a}
SED	0.06	0.03	0.04
Significance	*	*	*
Interaction M X D	NS	NS	NS
Interaction M X N	NS	NS	NS
Interaction D X N	NS	(0.1)	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing; N=Nitrogen levels and SED=Standard error of difference.

Higher rainfall amount coincided with grain filling and maturity stage in wheat might cause lesser grain yield due to water logging during 2019-20 as compared to 2018-19. Study of microbial biomass carbon (MBC) during 2019-20, after 7 and 14 days of residue incorporation showed that highest value MBC in residue incorporation method (Table 13 &14) also supported lesser loss of grain yield in second year by residue incorporation method, as compared to other two practices.

Early sowing of wheat (D1) showed positive impact on yield by producing maximum grain yield to the tune of 5.9 and 5.5 t ha^{-1} during 2018-19 and 2019-20 respectively and these were also statistically different from other two dates of sowing. Pooling of grain yield for both years also showed significantly higher grain yield for first date of sowing followed by D2 and D3. Early sowing caused higher grain yield also supported by Balwinder-Singh *et al*., 2016; Gonsalves, 2013;Gathala *et al.*, 2011; Mahendra *et al*., 2017; Munir *et al., 2002;* Tanveer *et al.*, 2003; Tomar *et al*., 2014; Tahir *et al*., 2009. The reason to get higher yield with early sowing may be longer growing period of crop, avoiding terminal heat stress, more radiation use efficiency , good growth of vegetative parameters like leaf number, size of leaves, more number of tillers, increased number of spikes per plant, grains per spike, 1000-grain weight etc.

Table 13. Microbial Biomass Carbon (MBC) for 2019-20 after 7 days of residue management

Treatments	**K_2SO_4 extracted soils (µg C g^{-1})**		
	Fumigated	**Non-fumigated**	**MBC**
Residue Incorporation	562	225	337
Residue Removal	375	114	261
Residue Burning	262	40	222

Table 14. Microbial Biomass Carbon (MBC) for 2019-20 after 14 days of residue management

Treatments	K_2SO_4 extracted soils (µg C g^{-1})		
	Fumigated	**Non-fumigated**	**MBC**
Residue Incorporation	856	509	347
Residue Removal	698	418	280
Residue Burning	314	75	239

While studying third aspect affecting the grain yield i.e. N levels, it is revealed that with increased nitrogen dose from 50% to 100% of recommended, increase in grain yield was observed for 2018-19 and 2019-20 years. This may be because of role played by N in enhancing the vegetative growth and photosynthetic efficiency of plants led to higher dry matter and yield (Belete *et al*., 2018). Sticksel *et al*., (2000) revealed improvements in wheat productivity and its contributing attributes under the adequate increasing N. During 2018-19, significantly highest yield of grains (5.7 t ha^{-1}) and in 2019-20 it was 5.3 t ha^{-1} due to recommended dose of N was noticed. Similar grain yield trend was also observed for pooled grain yield with maximum value of 5.6 t ha^{-1} at 100% N dose. These results are similar to Melaj *et al*., (2003) who indicated increased yield (grain) and the grain number m^{-2} with higher N rates.

All interactions were found non-significant for grain yield during 2018-19 and 2019-20 except relationship between dates of sowing and levels of N (Fig 20). During 2019-20, significant interaction was observed between methods and nitrogen levels. At 50% N, both D1 and D2 performed in similar way w.r.t grain yield, while with increase of N to 75% and 100%, timely sowing wheat performed better compared to D2 in increasing grain yield. Sowing on 20th December lagged behind in producing grain yield at all N level. Decline in grain yield of D3 @ 13, 16 and 16% than D1 (20th November) was observed.

Higher yield by interaction of higher nitrogen dose combined with residue incorporation was also reported by Khatri (2019); Yang *et al*., (2018); Su *et al*., (2014); Wang *et al*., (2014); Karami *et al*., (2012). All interactions in average grain yield of two years were found non-significant.

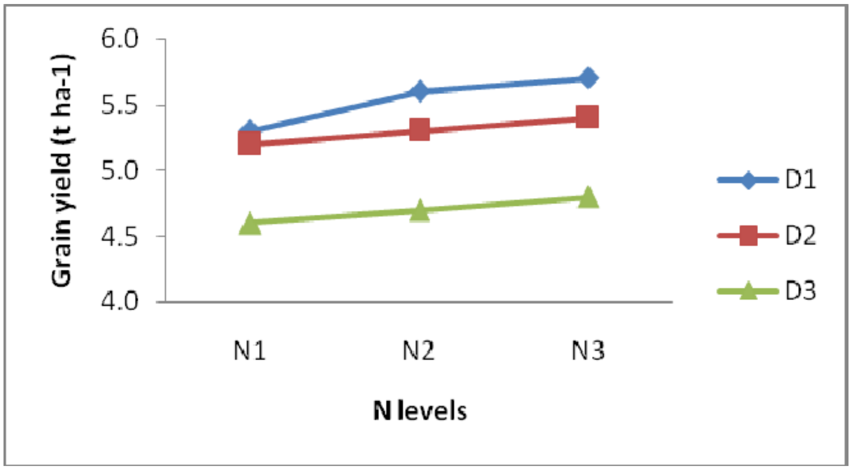


Fig 20. Interactive effect of sowing dates and N levels on grain yield during 2019-20

4.1.8 Straw yield (t ha^{-1})

Pooled straw yield showed significant maximum value (12.2 t ha^{-1}) for residue burning (M3) followed by residue removal (9.8 t ha^{-1}) and incorporation methods (9.6 t ha^{-1}). Significantly lowest straw yield was found under residue incorporation (M2), may be due to more partitioning of assimilates towards grain filling and increasing grain weight and grain yield as compared to straw component.

Among different dates of sowing delayed sowing up-to 15 days and 30 days reduced straw yield in wheat by 6% (D2) and 15% (D3) from the first date of sowing (D1). Straw yield of N3 level was highest (10.8 t ha^{-1}) followed by N2 and N1 (Table 15), may be due to more translocation of nitrogen to vegetative parts.

These results are supported by Sanjeevaradi (2001); Panda *et al*., (1988) and Verma *et al*., (2000). Interaction among all the three variables and between planting times and nitrogen levels was recorded not significant in terms of yield (straw), however other interactions were significant.

Table 15. Pooled straw yield (t ha^{-1}), biomass (t ha^{-1}) and Harvest Index (%) in wheat as influenced by various treatments during study period (2018-19 & 2019-20)

Treatments	Straw yield	Biomass	Harvest Index
Wheat Establishment Methods			
Residue Removal (M1)	9.8^{b}	15.2^{b}	35.8^{b}
Residue Incorporation (M2)	9.6 ^{b}	15.1$_{b}$	36.8^{a}
Residue Burning (M3)	12.2^{a}	17.5^{a}	30.7^{c}
SED	0.09	0.08	0.23
Significance	*	*	*
Dates of Sowing			
20th November (D1)	11.4 ^{a}	17.2^{a}	33.7^{b}
5$_{th}$ December (D2)	10.8 ^{b}	16.1^{b}	34.0^{b}
20th December (D3)	9.4 ^{c}	14.6^{c}	35.7^{a}
SED	0.09	0.09	0.26
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	10.1 ^{b}	15.4 ^{c}	34.9^{a}
75% Rec N (N2)	10.6 ^{a}	16.1 ^{b}	34.1^{b}
100% N (N3)	10.8 ^{a}	16.4 ^{a}	34.3^{b}
SED	0.09	0.09	0.26
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	*	*	*
Interaction D X N	NS	*	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

4.1.9 Biomass (t ha^{-1})

Average biomass of two years was found significantly higher (17.5 t ha^{-1}) under residue burning followed by residue removal and incorporation treatments (15.2 t ha^{-1}) as shown in table 15. Biomass was highest (17.2 t ha^{-1}) for first date of sowing followed by other two dates of sowing with almost 6 and 15% decline compared to early/timely sowing. Lesser biomass by delayed sowing may be due to smaller vegetative growth phase as supported by Dagash *et al*., (2014).

When levels of N application are compared, it is evident that recommended dose of nitrogen (N3) contributed more towards increase in biomass compared to lesser doses. While reduction in biomass due to 50% and 75% N was to the tune of 8 and 2% respectively. Reduced biomass at lower level of nitrogen with residue incorporation may be due to short term nitrogen immobilization and less soil moisture available to the plants. Nitrogen fertilizer enhances vegetative growth and dry matter was supported by Ashrafi *et al*., 2010 who observed significantly higher wheat biomass with additional nitrogen fertilizer. These results are also supported by Lingan (2015); Schmidt *et al*., (2004); Pathak *et al*., (2006) and Cucu (2014) by reporting decline in yield with low level of nitrogen applied.

Interactions between methods and dates, methods and N levels, dates and N levels found significant in terms of producing biomass. However relationship among all the factors was not noteworthy for biomass production (Table 15).

4.1.10. Harvest Index (%)

Although highest biomass and straw yield was obtained under third method of wheat establishment (M3), but significantly higher value of harvest index for residue incorporation method (M2) was noticed followed by removal and burning methods. It may be due to translocation of nutrients more towards increasing grain yield as compared to straw yield.

For different dates of sowing, significantly highest HI was for D3 and other two sowing dates remained at par. The results are in contrary to Dagash *et al*., (2014) who reported more harvest index in early sown wheat may be due to longer vegetative phase, higher photosynthesis and partioning of photosynthates more towards grains than straw. In case of influence of nitrogen levels, significantly harvest index observed was highest for 50% N followed by other two levels which were at par (Table 15). That means increased N levels also increased biomass along with contribution towards grain yield. While, interaction of methods, dates and N levels in terms of harvest index was found non-significant, but significant for interaction of methods with dates as well as N levels.

4.2 Effect of wheat establishment methods, sowing schedules and nitrogen levels on available nitrogen and nitrogen use efficiency

4.2.1 Available N (kg ha^{-1})

During study periods, available nitrogen was determined (Table 16). For 2018-19 maximum available N was observed for residue incorporation @ 257 kilo in a hectare and was statistically more than M3 followed by M1. Similar trend in available N was found during second year of study i.e. 2019-20 though highest value was 255 kg ha^{-1} here under the same treatment. The difference of available N in both years might be due to weather and soil conditions. For pooled nitrogen, it showed similar results with highest value of 256 kg ha^{-1} followed by residue burning and residue removal. These results are in agreement with Mandal *et al*., (2004) who found highest available N in residue inclusion followed by burning and removal may be due to more microbial biomass carbon.

Table 16. Available N (kg ha^{-1}) as influenced by various treatments

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	249.3^{c}	248.5 c	248.9 ^{c}
Residue Incorporation (M2)	257.0^{a}	255.2 a	256.1 ^{a}
Residue Burning (M3)	253.9^{b}	252.6 b	253.2 ^{b}
SED	0.77	0.58	0.65
Significance	*	*	*
Dates of Sowing			
20th November (D1)	256.6 a	255.0 a	255.8 ^{a}
5th December (D2)	252.9 b	251.5 b	252.2 ^{b}
20th December (D3)	250.7 c	249.7 c	250.2 ^{c}
SED	0.60	0.48	0.45
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	250.8 c	250.2 c	250.5 ^{c}
75% Rec N (N2)	253.3 b	252.1 b	252.7 ^{b}
100% N (N3)	256.2 a	253.9 a	255.0 ^{a}
SED	0.60	0.48	0.45
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	*	NS	NS
Interaction D X N	NS	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing; N=Nitrogen levels and SED=Standard error of difference.

When different dates of sowing were compared with respect to available N, significantly higher available nitrogen was obtained for first date of sowing followed by other two dates during both years independently and combined with highest values to the tune of 256.6, 255.0 and 255.8 kg ha^{-1} respectively. As per elevated nitrogen levels, available N also showed an increase as shown in table 16.

The results are justified by the report of Sanjeevradi (2001) and Parmar and Sharma (2001). They observed high available N with higher dose of N upto 125 kg ha^{-1} and with variation between N levels, available N differed significantly.

Interaction among all the three factors was found non-significant during each year of study as well as pooled available nitrogen. However, interaction was found significant for methods and dates of sowing.

4.2.2 Grain N uptake (kg ha^{-1})

Nitrogen uptake in grains symbolized yield response to nitrogen application rate. N uptake recorded at par in M1 and M2 treatments during 2018-19 followed by M3. This might be due to higher grain yield and less nitrogen availability to first year of incorporation of crop residue. During next year also trend of N uptake remained same. Least values of N uptake were observed under burning method to the tune of 82 and 77.4 kg ha^{-1} during the years 2018-19 and 2019-20 respectively (Table 17). While comparing both years, N uptake was more during 2018-19 than 2019-20. The reason might be that at the time flowering and grain filling more rainfall and higher temperature reduced the grain yield, so the N uptake in grains. During first year of study lesser value of grain N uptake than removal may be due to nitrogen immobilization and subsequently during 2019-20, it increased because of more decomposition by microbes and mineralization of N by residue incorporation as inclusion of residues enhances soil O.M. and recycled nutrients (Kone *et al*., 2010). Pooled analysis of both years showed highest grain N uptake (92.9 kg ha^{-1}) which was also at par with residue removal treatment followed by residue burning (79.7 kg ha^{-1}).

Table 17. N uptake (kg ha^{-1}) in wheat grains as influenced by various treatments

Treatments	2018-19	2019-20	Mean (18-19 & 19-20)
Wheat Establishment Methods			
Residue Removal (M1)	96.5 a	88.0a	89.7 a
Residue Incorporation (M2)	95.9a	90.0a	89.0 a
Residue Burning (M3)	82.0b	77.4b	80.5 b
SED	0.56	1.07	0.37
Significance	*	*	*
Dates of Sowing			
20th November (D1)	98.1 a	91.0a	94.5 a
5th December (D2)	91.2 b	85.0b	88.0 b
20th December (D3)	85.1 c	79.4c	76.7 c
SED	1.0	0.75	0.49
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	88.6c	82.3c	83.9c
75% Rec N (N2)	91.3b	84.5b	86.4b
100% N (N3)	94.5a	88.6a	89.0a
SED	1.0	0.75	0.49
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	*	*	*
Interaction D X N	NS	NS	NS
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at P≤0.05 using pair wise comparison test. NS=Non-significant;*=Significant at P≤0.05;M=Methods; D=Dates of sowing;N=Nitrogen levels and SED=Standard error of difference.

Among different dates of sowing, for first date of sowing grain N uptake was found maximum (98.1, 91, 94.5 kg ha^{-1}) during 2018-19, 2019-20 and also in pooled analysis respectively.

Nitrogen applied at varying rates also affected the grain N uptake as presented in table 17. With increasing dose of nitrogen fertilizer, grain N uptake increased. This increase was statistically higher for 100% RDN during 2018-19 with N uptake by grain

(94.5 kg ha^{-1}), while during 2019-20, this value was 88.6 kg ha^{-1} again highest under the highest level of N taken. However, pooled highest uptake of N was 91.4 kg ha^{-1} followed by other two lower levels. These results are also in line with the findings of Dotaniya, 2013 who stated that N uptake in wheat was higher with application of 50 kg N ha^{-1} higher dose.

High rainfall during 2019-20 at reproductive stage might reduce the N uptake in plants under different treatments. Additionally, the highest nitrogen uptake by the grain in both growing seasons at the highest N rate might be due to the ample N availability for the crop. Reduction in grain yield also reduced the nitrogen uptake by the grain. These results are also justified by Belete *et al*., (2018). These results are corroborated with Yesuf and Duga (2000) who reported that increased N rate and also genetic differences caused significant increase in grain nitrogen uptake.

It is revealed form the table 17 that interactions of MXD and MXN are significant that means not only sowing dates and N levels are affecting the uptake of N by the plant grains, but also methods in combinations with these are influencing uptake of nitrogen.

4.2.3 Total N uptake (kg ha^{-1})

The total N uptake also showed the biomass response to methods, dates and nitrogen levels. Total N varied appreciably between methods, N rates and dates of sowing. Total N uptake during 2018-19 showed non-significant difference among different methods with highest value as 131.9 kg ha^{-1} in residue removal (Table 18). During second year, methods M1 and M2 remained statistically at par with respect to total N uptake and showed higher uptake compared to residue burning method (M3).

While comparing, dates of sowing it was observed that early sowing of wheat (D1) observed significantly higher total N uptake during both years (2018-19 & 2019-20) i.e. 142.3 kg ha^{-1} and 131.1 kg ha^{-1} respectively may be due to longer vegetative period. Pooled total N uptake showed maximum value of N uptake under 20th November as 136.8 kg ha^{-1} followed by 125.3 and 114.4 kg ha^{-1} for 5th December and 20th December sowing of wheat.

Table 18. Total N uptake (kg ha^{-1}) in wheat (grain+ straw) under various treatments

Treatments	**2018-19**	**2019-20**	**Mean (18-19 & 19-20)**
Wheat Establishment Methods			
Residue Removal (M1)	131.9	124.7^{a}	126.3^{a}
Residue Incorporation (M2)	130.7	125.7^{a}	125.1^{a}
Residue Burning (M3)	128.2	112.0^{b}	120.8^{b}
SED	0.70	1.34	0.51
Significance	NS	*	*
Dates of Sowing			
20^{th} November (D1)	142.3^{a}	131.1^{a}	136.8^{a}
5_{th} December (D2)	130.4^{b}	120.5^{b}	125.4^{b}
20^{th} December (D3)	118.3^{c}	110.7^{c}	110.0^{c}
SED	1.09	0.84	0.65
Significance	*	*	*
Nitrogen Levels			
50% Rec.N (N1)	127.8_{b}	117.0^{c}	121.2^{c}
75% Rec N (N2)	130.5_{a}	120.7^{b}	124.5^{b}
100% N (N3)	132.7_{a}	124.6_{a}	126.6^{a}
SED	1.09	0.84	0.65
Significance	*	*	*
Interaction M X D	*	*	*
Interaction M X N	NS	*	*
Interaction D X N	NS	*	*
Interaction M X D X N	NS	NS	NS

Means along the same column with different letter(s) are unlike at $P \leq 0.05$ using pair wise comparison test. NS=Non-significant;*=Significant at $P \leq 0.05$;M=Methods; D=Dates of sowing; N=Nitrogen levels and SED=Standard error of difference.

Out of all three nitrogen levels, total N uptake showed an increase with increasing N rates during both years and pooled N uptake also. Maximum total N uptake was noticed with 100 % RDN, though statistically similar for all N rates during 2018-19. Similar trends were found for 2019-20 with highest N uptake to the tune of 124.6 kg ha^{-1} followed by 120.7 and 117.0 kg ha^{-1} for 75% and 50% RDN respectively.

However by considering average of both years of study, these value were 128.6, 125.5 and 122.4 kg ha^{-1} respectively for 100, 75 and 50% RDN. The interaction between methods and dates is significant in terms of total N uptake in wheat during both years. Interaction between methods and nitrogen levels was significant during 2019-20, but non significant during 2018-19. However interaction among all three factors was non-significant for the year 2018-19, 2019-20 and in pooled N uptake also.

4.2.4 Nitrogen Harvest Index (NHI %)

Nitrogen Harvest Index is calculated as the ratio of nitrogen in grain to the nitrogen in grain + straw. According to Fagaria (2014), NHI is the indicator of plant efficiency to utilize nitrogen for formation of grains. A high value of NHI means better utilization of N. In present study, pooled NHI (%) was recorded maximum (77%) for residue removal method interacted with 20th December sowing and 100 % RDN (Table 19). From the maximum NHI value, a highest decline of almost 17% observed in combination of M3D1N2 followed by M3D2N1 and M3D2N3, while the least variation was for M1D2N3. Significant lesser NHI % was recorded for residue burning method.

For the year, 2019-20 trend of NHI was similar as in pooled data, highest value of NHI % (76.9 %) again was in M1D3N3 and least decline from this maximum value was observed in M1D3N2 and maximum decline was about 13% in residue burning method adopted for wheat sowing on first date (20th November) and applied with 50% RDN (Table 20).

Pooled NHI% is presented in table 21 showed similar trend as in both the years with maximum NHI of 75.9 % for M1D3N3 followed by M1D2N3 and M2D1N3 with values 75.2 and 73.3% respectively.

Table 19. Interaction effect of sowing methods (M), dates of sowing (D) and nitrogen levels (N) on Nitrogen Harvest Index (%) of wheat during 2018-19

Sowing Methods	**Dates of sowing**	**N levels**		
		50% N	75% N	100% N
Residue Removal	20th November	70.7	72.4	71.6
	5th December	69.6	73.8	76.9
	20th December	72.9	73.2	77.2
Residue Incorporation	20th November	71.7	72.3	73.2
	5th December	74.6	72.8	74.4
	20th December	74.4	73.6	73.4
Residue Burning	20th November	63.4	60.5	64.5
	5th December	60.9	63.7	62.1
	20th December	66.9	67.2	66.9
CD (5%)	**3.1**			

Table 20. Interaction effect of sowing methods (M), dates of sowing (D) and nitrogen levels (N) on Nitrogen Harvest Index (%) of wheat during 2019-20

Sowing Methods	Dates of sowing	N levels		
		50% N	75% N	100% N
Residue Removal	20th November	69.0	69.3	67.5
	5th December	69.6	72.0	68.0
	20th December	67.8	73.6	76.9
Residue Incorporation	20th November	72.1	71.8	63.9
	5th December	72.2	69.8	69.8
	20th December	71.6	71.2	72.8
Residue Burning	20th November	63.4	73.4	67.0
	5th December	60.9	72.0	67.5
	20th December	66.9	70.3	72.5
CD (5%)	**2.4**			

Table 21. Interaction effect of sowing methods (M), dates of sowing (D) and nitrogen levels (N) on Nitrogen Harvest Index (%) of wheat in pooled data

Sowing Methods	Dates of sowing	N levels		
		50% N	75% N	100% N
Residue Removal	20th November	69.8	70.8	70.8
	5th December	69.6	72.9	75.2
	20th December	70.4	71.5	75.9
Residue Incorporation	20th November	71.9	72.0	73.3
	5th December	73.4	71.3	73.2
	20th December	73.0	72.4	71.9
Residue Burning	20th November	65.5	62.3	65.7
	5th December	64.5	66.7	64.8
	20th December	71.9	69.9	69.7
CD (5%)	**2.4**			

Among the sowing dates, NHI was statistically at par for pooled NHI in residue incorporation method for all levels of RDN. That means different dates of sowing are not affecting the nitrogen harvest index. Sinebo *et al.,* (2004) reported NHI in durum wheat @an average NHI more than 70% depending on timing and doses of N application.

Almost statistical similar or at par NHI was observed for 20thNov. and 5th Dec. sowing with all levels of nitrogen when method of wheat establishment chosen was residue burning (M3), however, higher values for 20th December sowing was obtained as evident in table 21.

Relationship between available N and total N uptake showed a strong interaction between these two variables for residue incorporation with highest correlation coefficient and coefficient of determination values may be due to better utilization of available N and its contribution towards yield increase for both years. Highest correlation coefficient and coefficient of determination worked out were 0.98 and 0.96 respectively for 2018-19 (Table 22) while, these were 0.96 and 0.92 for 2019-20 (Table 23). In both cases, least values were observed under residue burning treatments. Similar results were observed by Shiwakoti (2018) for wheat crop.

Table 22. Relationship between Available N(kg ha^{-1}) and Total N uptake (kg ha^{-1}) under different methods for 2018-19

Methods	Correlation coefficient (r)	Coefficient of Determination (R^2)	Regression equation
Residue Removal (M1)	0.83	0.69	2.31x-444.5
Residue Incorporation (M2)	0.98	0.96	1.85x-345.2
Residue Burning (M3)	0.30	0.09	1.36x-217.5

Table 23. Relationship between Available N(kg ha^{-1}) and Total N uptake (kg ha^{-1}) under different methods for 2019-20

Methods	Correlation coefficient (r)	Coefficient of Determination (R^2)	Regression equation
Residue Removal (M1)	0.92	0.85	2.57x-514
Residue Incorporation (M2)	0.96	0.92	1.63x-290
Residue Burning (M3)	0.37	0.14	3.07x-663

4.3 Effect of wheat establishment methods, sowing schedules and nitrogen levels on economical benefits

The economic analysis of different wheat establishment methods through rice residue management, sowing schedules and nitrogen levels was conducted by taking into account the cost of cultivation, total and net income in 10,000 m^2 under different treatment combinations and presented in tables 24, 25 & 26. Among three methods, maximum cost of cultivation was under residue removal, third date of sowing and highest level of nitrogen application (M3, D3 and N3) may be due to more labour requirement for removal process of residue, making bundles and transportation of this to other site. With progress of dates of sowing, cost increased to some extent as seed rate has to be increased 5-10 kg ha^{-1} for better crop stand. Similarly cost of N application was higher in 100% N as compared to 75 and 50% (Table 24). Net returns i.e. gross returns minus cost of cultivation was found highest for residue burning treatment due to low cost of cultivation followed by residue incorporation and residue removal though grain yield were not varied too much (Table 25). Benefit cost ratio followed similar trend as net returns with highest value of 2.29 for residue burning with first date of sowing and 75% RDN during 2018-19 and 2.25 with third method, first date of sowing but with 100% applied nitrogen during 2019-20 (Table 26). These results are in agreement with Haider, 2012 who stated that farmers were more benefitted from residue burning due to higher yield and lesser cultivation expenditure. Least value of benefit cost ratio was observed in residue removal method with late sowing by 30 days from the normal sowing date and application of nitrogen at 50% than recommended, however as the level of N increased this ratio increased to some extent.

Table 24: Effect of various treatments on cost of cultivation (Rs ha^{-1}) in wheat during 2018-19 and 2019-20

Sowing Methods	Dates of sowing	N levels		
2018-19				
Residue Removal		50% N	75%N	100%N
	20th November	61200	61850	62500
	5th December	61450	62100	62750
	20th December	61650	62300	62950
Residue Incorporation	20th November	57700	58350	59000
	5th December	57900	58550	59200
	20th December	58100	58750	59400
Residue Burning	20th November	46250	46850	47450
	5th December	46400	47000	47600
	20th December	46600	47200	47800
2019-20				
Residue Removal	20th November	61350	62000	62650
	5th December	61600	62250	62900
	20th December	61800	62450	63100
Residue Incorporation	20th November	57850	58500	59150
	5th December	58050	58700	59350
	20th December	58250	58900	59550
Residue Burning	20th November	46400	47000	47600
	5th December	46550	47150	47750
	20th December	46750	47350	47950

Table 25: Effect of various treatments on net return (Rs ha^{-1}) in wheat during 201819 and 2019-20

Sowing Methods	Dates of sowing	N levels		
		50% N	75%N	100%N
Residue Removal	20th November	44250	49150	48500
	5th December	40300	45200	46400
	20th December	36400	37600	40650
Residue Incorporation	20th November	49600	52650	55700
	5th December	47550	48750	48100
	20th December	43650	43000	44200
Residue Burning	20th November	59200	60450	56150
	5th December	51650	52900	52300
	20th December	47750	47150	48400
2019-20				
Residue Removal	20th November	40050	43300	46550
	5th December	37850	37200	40450
	20th December	33750	35050	38300
Residue Incorporation	20th November	49400	52650	57850
	5th December	43350	44650	47900
	20th December	39250	40550	41850
Residue Burning	20th November	55000	56350	59650
	5th December	52900	54250	55600
	20th December	50750	46250	45650

Table 26: Effect of various treatments on B: C ratio in wheat during 2018-19 and 2019-20

Sowing Methods	Dates of sowing	N levels		
		50% N	75%N	100%N
Residue Removal	20th November	1.72	1.79	1.78
	5th December	1.66	1.73	1.74
	20th December	1.59	1.60	1.65
Residue Incorporation	20th November	1.86	1.90	1.94
	5th December	1.82	1.83	1.81
	20th December	1.75	1.73	1.74
Residue Burning	20th November	2.28	2.29	2.18
	5th December	2.11	2.13	2.10
	20th December	2.02	2.00	2.01
2019-20				
Residue Removal	20th November	1.65	1.70	1.74
	5th December	1.61	1.60	1.64
	20th December	1.55	1.56	1.61
Residue Incorporation	20th November	1.85	1.90	1.98
	5th December	1.75	1.76	1.81
	20th December	1.67	1.69	1.70
Residue Burning	20th November	2.19	2.20	2.25
	5th December	2.14	2.15	2.16
	20th December	2.09	1.98	1.95

4.4 Evaluation of field experiments by crop model

4.4.1 Calibration, validation and simulation for study area

InfoCrop model was calibrated by comparing yield data of field experiments and simulated yield for three years. Model was calibrated for wheat crop variety-HD 3086 for years according to crop data availability. Crop specific thermal time was calculated based on the values of mean temperature minus base temperature. Generic coefficients used in calibration process are presented in table 27 and results of validation are given in table 28. Then the coefficient of efficiency was calculated by using the equation given by Hubbard *et al*., (2003).

Table 27. Generic coefficients used for simulation of wheat crop

S.No.	**Parameters used**	**Variety-HD 3086**
1	Thermal time (°C days)	
A	Sowing to germination	70
B	Germination to 50% flowering	800
C	50% flowering to physiological maturity	400
2	Radiation use efficiency (g/MJ/day)	2.8
3	Specific leaf area (dm2/mg)	0.002
4	Potential storage organ weight (mg/grain)	39
5	Date of sowing	20^{th} November, 5^{th} December and 20^{th} December
6	Seed rate (kg/ha)	100 kg/ha

Table 28. Validation results for wheat crop

Date of sowing	Coefficient of Efficiency (%)	RMSE kg ha^{-1}	MAE kg ha^{-1}
20th November	80.6	101.5	213.5
5th December	82.4	81.2	108.1
20th December	82.4	31.4	51.1

RMSE-Root mean square error; MAE- Mean absolute error

After calibration and validation, sensitivity analysis of model and then simulation was done for three years from 2017-2019.

Sensitivity analysis was performed by increasing temperature and CO_2 concentration in the model upto 414 ppm (HadCM3 A2 Scenario given by IPCC) for 2010-2039 to know the function of projected changes of mean, maximum and minimum temperature in various combinations at current and projected levels of CO_2 on potential yield. The study was done by increasing the maximum, minimum and both maximum and minimum temperatures from 1 to 2˚C. Potential yield of wheat was first simulated for 370 ppm concentration of CO_2 and it was increased to 414 ppm.

Results of sensitivity analysis given in fig 21 showed that almost 26% decline in potential yield of wheat may be observed by increasing maximum temperature as well as both maximum and minimum temperatures at 414 ppm CO_2 level as compared to without increment in temperature and CO_2 level. It was also observed that yield decline projected for 1˚C maximum temperature addition was higher as compared to 1˚C increment in minimum temperature. With 2˚C increase in maximum temperature, projected yield decline was 15%, 12% and 14% respectively for the crop seasons of 2017-18, 2018-19 and 2019-20.

On the contrary, by increasing minimum temperature by 2˚C, either similar or more decline in potential yield was observed compared to same increment in maximum temperature. That means increase in minimum temperature can cause more yield loss in wheat in future may be due to higher respiration losses. However, 1˚C increase in mean temperature caused a decline in yield ranged from 20-26%, but 2˚C rise in mean temperature led to a decline of 19-25%. Similarly decline in yield with increase in temperature also observed by Haris *et al*., (2013) in Bihar.

Simulations of crop grain yield were done by considering only one method (i.e. residue burning) most common in Punjab .Results of simulation are presented in table 29. Coefficient of efficiency varied from 80 to 86%, least in the combination i.e. third date of sowing with 75% of nitrogen and maximum efficiency was recorded for first date of sowing with 50% recommended N. However, maximum root mean square error (RMSE) and mean absolute errors (MAE) were 361 kg $ha^{-1}$and 564 kg ha^{-1} for D2N2. Fig 22 (a-i) showed the nearness of predicted yield to observed yield under different combinations.

Table 29. Simulation for wheat crop under different treatments

Dates of sowing	**Nitrogen Levels**	**Coefficient of Efficiency (%)**	**RMSE** kg ha^{-1}	**MAE** kg ha^{-1}
20th November	50% N	85.8	338.3	496.8
5th December	75% N	80.7	317.1	455.4
20th December	100%N	81.6	284.2	412.0
20th November	50% N	80.4	315.7	490.3
5th December	75% N	81.7	361.4	564.0
20th December	100%N	82.5	319.8	480.4
20th November	50% N	80.7	328.0	420.0
5th December	75% N	80.6	265.2	362.0
20th December	100%N	81.1	275.0	403.0

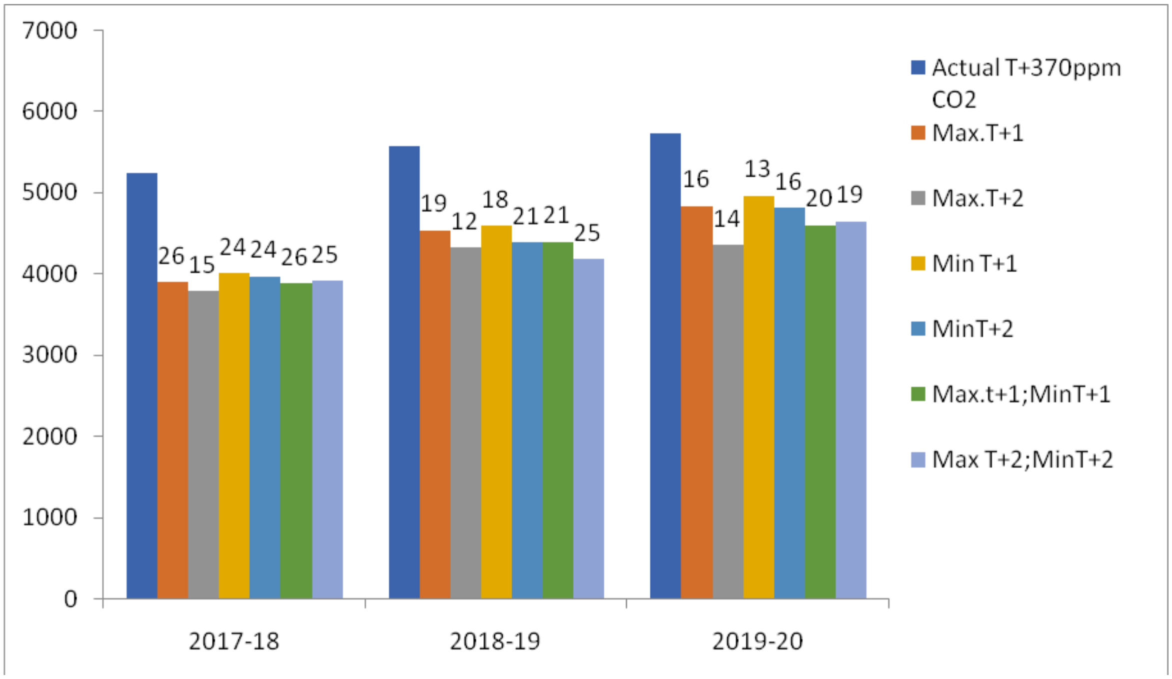
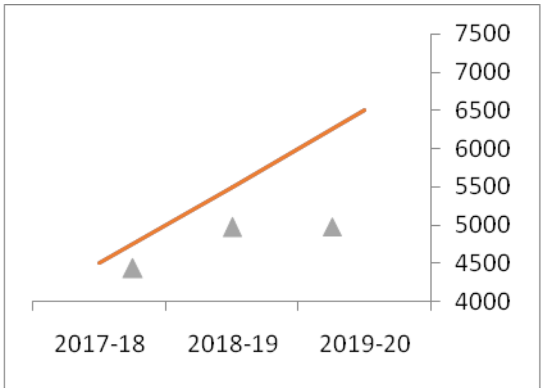
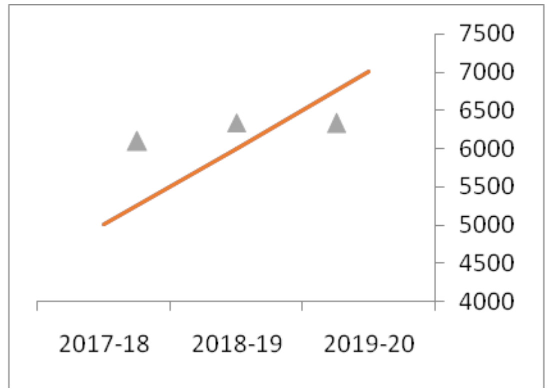


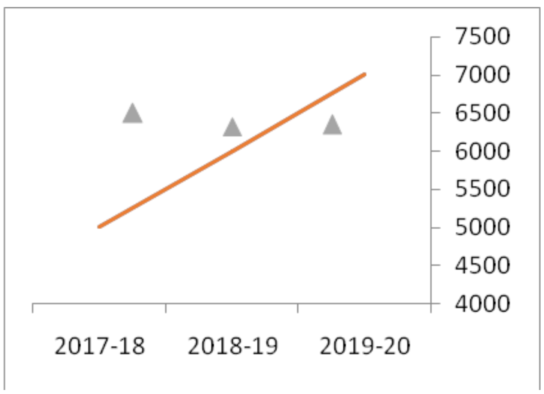
Fig 21. Changes in grain yield (kg/ha) of wheat (D3N1) with increasing temperature and CO_2 level


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

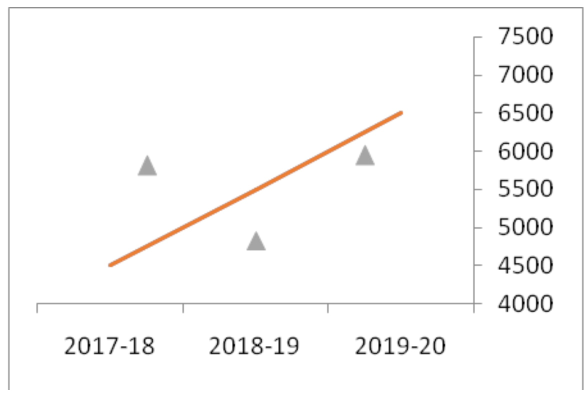
(a)


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

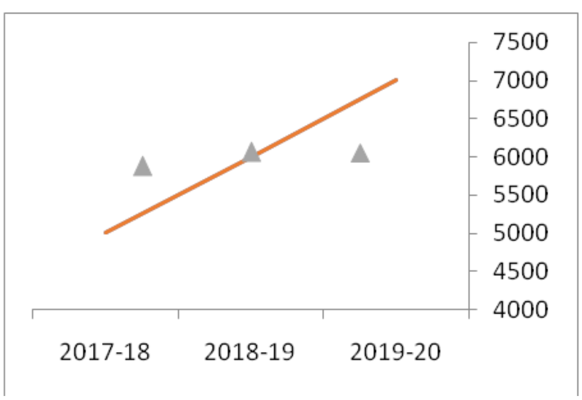
(b)


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

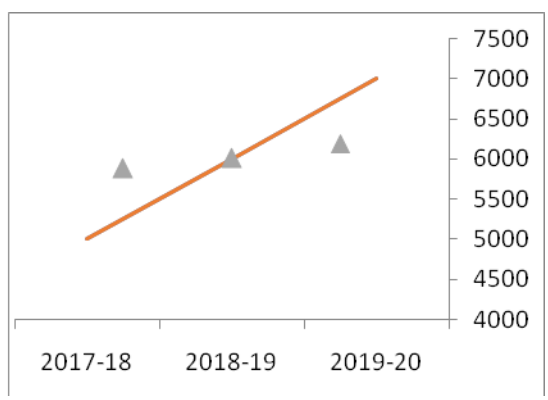
(c)


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

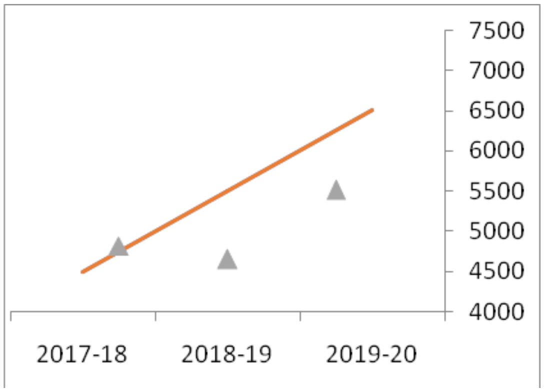
(d)


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

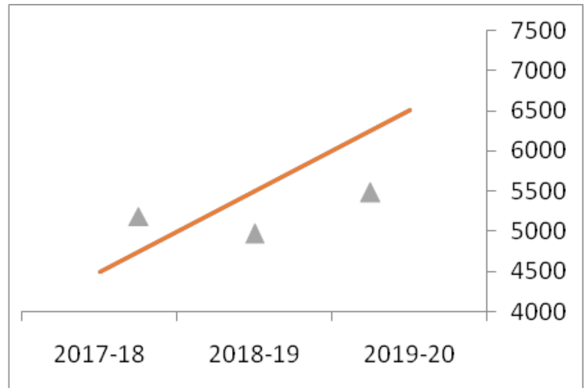
(e)


7500
7000
6500
6000
5500
5000
4500
4000
2017-18
2018-19
2019-20

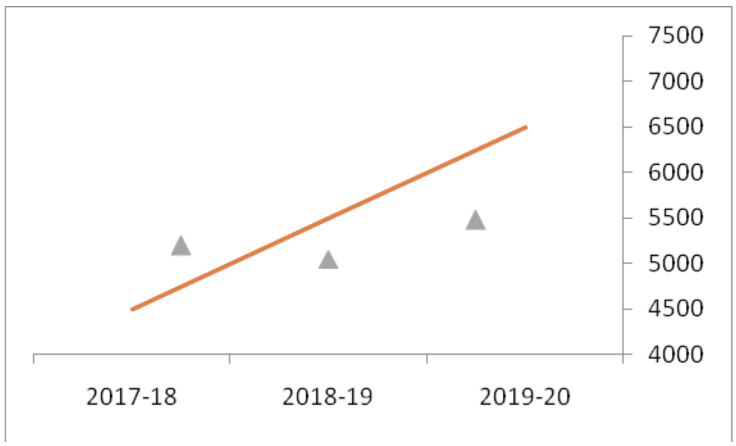
(f)



(g)



(h)



(i)

Fig 22. 1:1 Line graphs for observed versus predicted grain yield (kg/ha) in wheat for D1N1(a), D1N2(b), D1N3(c), D2N1(d), D2N2(e), D2N3(f) and D3N1(g), D3N2(h), D3N3 (i) for various combinations

Chapter-V

SUMMARY AND CONCLUSIONS

A field trial was carried out to study the impact of wheat establishment methods, sowing schedules and nitrogen levels on wheat growth and yield at Lovely Professional University, Phagwara, during *rabi* seasons of 2018-19 and 2019-20. A brief summary of the findings are given below.

In the investigation, treatments were laid out in split-split plot, assigning wheat establishment techniques to main plots and sowing schedules and levels of N combinations to subplots. During the investigation, different growth and yield contributing parameters viz. plant height, number of tillers per plant, number of spikes per plant, spike length, number of grains per spike, 1000-grain weight, grain yield, straw yield and biomass were recorded. Data on nitrogen availability in soil, grain N uptake, total N uptake by grain + straw was also recorded.

- Plant height was observed highest for residue burning method at 30, 60 and 90 DAS, except at harvest, where residue incorporation method showed highest plant height (91.9 cm) i.e. also statistically different from other two methods of wheat establishment.
- Out of three sowing dates and level of nitrogen applied, highest plant height (91.4 cm) that was statistically at par with 90 cm followed by 88 cm observed under D1, D2 and D3. However, recommended nitrogen produced highest plant height i.e. 91.7 cm followed by 75% and 50% RDN.
- At 30 DAS, tillers number in residue incorporation and burning treatments were statistically at par followed by removal of residue method. First date of sowing superseded in terms of tiller count (25.2). After 60 days of sowing trend remained the same as in 30 DAS for methods and sowing schedules. Nitrogen levels affected the tiller count by recommended dose as compared to lower dose.

- Among sowing schedules, wheat sowing on 20th November has given maximum number of effective tillers per plant (20.5) during 2018-19 and 2019-2020 (17.7) compared to delay sowing by 15 and 30 days. Residue incorporation method would produce maximum effective tillers higher from other methods in each year of study. 100% RDN produced maximum number of spikes per plant (17.7).
- Highest spike length (12.1 cm) was observed in residue incorporation during second year of study i.e. 2019-20. Pooled analysis also showed the similar result with 11.1 cm spike length significantly higher than other two methods. Statistically similar pooled spike length was obtained for 50% and 75% N, but highest for 100%N.
- Pooled data over two years showed maximum grains per spike to the tune of 43.7 in M3 (Residue burning). By comparing the mean grains per spike for two years, first date of sowing and 100% N gave the best results.
- Average of two years' data showed statistically similar seed index for residue incorporation and residue removal treatments followed by residue burning. Maximum seed index was found for first sowing date and recommended rate of nitrogen.
- During 2019-20, statistically elevated grain yield i.e. 5.3 t ha^{-1} was obtained under residue incorporation method followed by residue burning and residue removal. Combined results of both years in terms of grain yield showed statistically no significant difference of yield between residue removal and burning methods of wheat establishment. First date of sowing with 100% nitrogen produced highest yield (5.7 and 5.6 t ha^{-1}) during both the years.
- Significantly higher straw yield (12.2 t ha^{-1}) but lowest harvest index (30.7%) was found under residue burning. Among different dates of sowing delayed sowing upto 15 days and 30 days reduced straw yield in wheat by 5% and 21% from the first date of sowing. Straw yield of N3 level was highest followed by N2 and N1.

- Highest biomass was recorded under residue burning followed by residue removal and incorporation treatments. Biomass was also highest (17.2 t ha^{-1}) for first date of planting and third level of N (16.4 t ha^{-1}) among all dates and nitrogen levels.
- Harvest index, was significantly highest (36.8%) for residue incorporation method of wheat sowing followed by residue removal and residue burning. For nitrogen levels, 75% and 100% RDN treatments were statistically similar.
- Maximum available N was found for residue incorporation method, first date of sowing and third level of nitrogen.
- Residue incorporation and residue removal methods were statistically similar in terms of grain N uptake. The variation in N uptake was significant among dates of sowing. With increasing dose of nitrogen fertilizer, grain N uptake increased.
- Total N uptake during 2018-19 showed non-significant difference among different methods. However, early sowing of wheat registered significantly higher total N uptake during both years (2018-19 & 2019-20). Out of all three nitrogen levels, total N uptake showed increasing trend with increasing N rates during both years and pooled N uptake also.
- Pooled NHI (%) was recorded maximum (76%) for residue removal method with 20^{th} December sowing and 100% RDN. Significantly lesser NHI was recorded for residue burning method. Maximum value of correlation coefficient and coefficient of determination was found for available and total N uptake by plant under M2 (Incorporation of residue) followed by M1 and M3.
- Among three methods, maximum cost of cultivation was under residue removal (Rs. 62950), third date of sowing and highest level of nitrogen application.
- Net returns were found highest for residue burning treatment followed by residue incorporation and residue removal due to more cost of cultivation in the later method than other two.
- Highest B:C was observed as 2.29 for 2018-19 and 2.20 during 2019-20 under M3 with 20^{th} November sowing and at 75% or 100% RDN respectively followed by second method (M2).

- Infocrop model was calibrated and validated with coefficient of efficiency varied from 80-82%. Sensitivity analysis showed that wheat yield may decline with increasing temperature and CO_2 level. Highest coefficient of efficiency (86%) was attained with first date of sowing and 50% recommended N combination.

Consciousness of the ecological outcomes of straw burning seems to be a considerable encouraging aspect for opting straw incorporation over burning. However, farmers' choice of removal of residues compared to burning not be affected in similar fashion due to the drastically higher cost of removal. Alternatives for plummeting the cost of gathering and moving of rice straw may lessen costs in the long run and augment the likelihood of the implementation of straw removal options including composting. To spread information regarding laws and regulations, campaigns and drives as well as strict implementation of laws are also the need of the hour. The above scenario suggests sure policy interventions to persuade farmers for giving up burning practice and incorporating rice residue in the field. Growing short duration varieties of paddy, varieties which produce lesser straw like basmati rice etc. so that rice residue can be incorporated and it gets decomposed properly before sowing of wheat. Timely sowing of wheat is essential to get higher grain yield and increasing economic benefits. Subsidies for new seed varieties, machinery, and technical education are other actions that can be taken to plead with farmers for accepting novel techniques.

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