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Effect of Seed Rates and Sowing Dates on Productivity of Wheat (*Triticum aestivum* L.)

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A B S T R A C T

A field experiment was conducted at the Agronomy farm of Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur to evaluate the effect of sowing dates and seed rates on yield and yield attributes of wheat. The experiment was laid in a split-plot design with three replications treated with 4 sowing dates as the main plot factor (12th Nov, 27th Nov, 12th Dec, and 27th Dec) and 4 seed rates as subplot factor (100 kg ha^{-1}, 120 kg ha^{-1}, 140 kg ha^{-1} and 160 kg ha^{-1}). Results revealed that the leaf area index was significantly affected by sowing dates and was comparatively superior in 2nd sowing date (27th Nov) wheat. Similarly, in the case of seed rates, the leaf area index was influenced significantly and was recorded to be increasing with an increase in seed rates. Phenological parameters like days to 50% heading, flowering, and maturity were observed maximum (116, 123, and 179 days, respectively) in early sown wheat and reduced with the subsequent delay in sowing. Maximum values of yield and yield attributes like effective tillers per meter square (635.6), spike length (9.56 cm), grains per spike (41.49), grain yield (7.59 Mt ha^{-1}), and straw yield (9.58 Mt ha^{-1}) were observed in the wheat sown in 2nd date (on 27th Nov) which differed significantly to wheat sown on other dates. Seed rates had no significant influence on grain yield and yield attributes. Thousand-grain weight was found maximum (46.26 g) in early sown wheat (on 12th Nov sown wheat, reduced with the subsequent delay in sowing, and the harvest index was observed as maximum (0.51) under December 27 sown wheat. Though the yield and its attributes were not influenced significantly by seed rate, the maximum yield (6.18 Mt ha^{-1}) was observed in wheat sown at the rate of 120 kg ha^{-1}. Considering seed yield and its parameters, 2nd date of sowing wheat (27th Nov) and seed rate of 100 kg ha^{-1} could be the best option to uplift the productivity of wheat in rainfed lowland conditions of Lalitpur, Nepal.

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Introduction

Wheat (*Triticum aestivum* L., 2n=42), also known as the king of cereals is an important source of food across the world. It belongs to the *Poaceae* family and globally, after maize, is the most widely cultivated cereal (Mourad et al., 2019; Ghahremaninejad, 2021). The extent of its success hinges on its adaptability and high yield potential, as well as the gluten protein fraction (Shewry, 2009; Sousa et al., 2021). Wheat cultivation has been a longstanding practice in Nepal, in various regions such as Terai, river basins, mid-hills, and high hills, occurring in the winter season from October to July. Though it is cultivated as a winter crop, differences in geography and topography makes the sowing period of wheat differ in different portions of the country (Poudel, 2013). It is produced on 0.70 million hectares of land in the country yielding about 2.2 million metric tons with a productivity of 3.08 Mt ha^{-1} (MoALD, 2020). There can be several factors which are responsible for low wheat productivity in the country like irrigation, fertilizer, climate, insects, pests, etc. but with proper management of the crop wheat production and productivity can be improved from the present scenario (Pokherel et al., 2007).

Sowing date and seed rate have always been a problem for the cultivation of wheat. Deviation from the optimal range of seed rate has an adverse effect on plant growth and yield. In the case of suboptimal seed rate, the available resources for plant growth are not efficiently utilized or even wastage of the resources occurs. Similarly, the use of more than optimal seed rate causes a dense population which makes the plant compete for radiant energy and other nutrients (Jan et al., 2000). Reducing the seed rate in the vegetative growth stage leads to decreased competition between plants. However, during the grain-filling phase, increasing the number of tillers intensifies competition within each plant (Shazma et al., 2015).

Early planting ensures optimum emergence through sufficient tiller number per unit area. However, each weak delay of sowing reduces the vegetative and reproductive phases and affects the yield-attributing characteristics leading to yield reduction (Akmal et al., 2011; Malik et al., 2009). Similarly, the sowing date had a greater influence on grain yield quantity and quality compared to seed rate. However, consistently lower yields were obtained with reduced seed rates (McKenzie et al., 2011).

Proper sowing date with optimal seed rate is the need of farmers growing wheat crops. So this experiment focuses on the relationship between sowing date and seed rate in wheat crops in the hilly region of the country. Effects of sowing date and varied seed rate under study may result in the finding of appropriate sowing time and optimal seed rate for better productivity in the regions of similar climatic conditions which in return can improve the overall production trend of wheat. The findings might be fruitful directly to the regions having similar climatic conditions of research site only which seems to be a limiting factor for considering the overall wheat production trend in the country.

Materials and Methods

Location

The experiment was conducted in the research field of the Agronomy Division of Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal from November 2020 to June 2021. The station is located at an elevation of 1360 meters above sea level.

Physio-chemical Characteristics of Experimental Soil

The soil of the experimental plot was tested by Nepal Agricultural Research Council (NARC) and the final soil status was provided. As per the available data, the soil was acidic in pH (5.98) containing low organic matter (2.01%), medium total Nitrogen (0.139%), high available P_2O_5 (478.6 kg ha^{-1}), and medium available K_2O (160.5 kg ha^{-1}). The soil texture was silty clay loam, and the average bulk density was 1.39 gm cm^{-3}(Table 1).

Climatic Conditions during Field Experimentation

Daily maximum and minimum temperatures for each month were recorded using maximum and minimum thermometer during the entire research period from November 2020 to June 2021. The maximum monthly average temperature (T_{max}= 27.8˚C and T_{min}=20 ˚C) was recorded in June and the minimum monthly average temperature was recorded in January (T_{max}=19.6˚C and T_{min}=3.5˚C). Daily rainfall for each month was recorded using rain guage and the total monthly rainfall was found higher in May (127.6 mm) and June (204 mm). Average relative humidity of 75±5 % was recorded (using hygrometer) for the entire research period (Figure 1).

Experimental Design and Treatments

The experiment was conducted in a split-plot design with two treatments and three replications. The sowing date was assigned as the main plot and the seed rate was assigned as a subplot in the experiment (Table 2).

Varietal Description

The variety under experimentation was WK3026 (zinc-fortified breeder seed). It was a pipeline variety that was under research by NARC and yet to be released at the period of the experiment. It was the variety that was foreseen as a promising one and of high potential from the previous trials done by the Division of Agronomy.

Field layout and crop geometry

A total of 48 plots with a dimension of 4m×3m was made with each plot consisting of 15 rows of wheat sown continuously at the spacing of 20 cm between the rows. A spacing of 0.75m between replication and 0.5m between plots was maintained. Ten rows were treated as net plot rows for harvesting, two for destructive sampling, and the other as guard rows.

Table 1. Physio-chemical characteristics of the soil in the experimental plot during 2020.

Soil Characters	Description
Soil texture	Silty clay loam
Soil pH	5.98
Bulk density	1.39 g cm^{-3}
Organic matter content	2.01%
Total nitrogen	0.139%
Available P_2O_5	478.6 kg ha^{-1}
Available K_2O	160.5 kg ha^{-1}

Source: NARC, 2021

Table 2. List of treatments used in the experiment.

Main plot factor A	Subplot factor B
1^{st} date of sowing (D_1) = 12 Nov. 2020	Seed rate (S_1) = 100 kg ha^{-1}
2^{nd} date of sowing (D_2) = 27 Nov. 2020	Seed rate (S_2) =120 kg ha^{-1}
3^{rd} date of sowing (D_3) = 12 Dec. 2020	Seed rate (S_3) = 140 kg ha^{-1}
4^{th} date of sowing (D_4) = 27 Dec. 2020	Seed rate (S_4) = 160 kg ha^{-1}

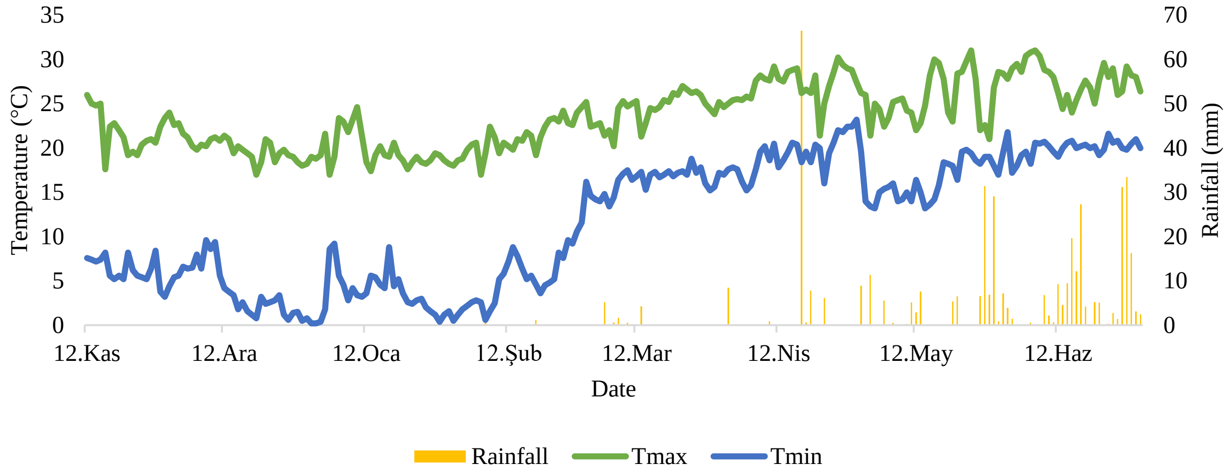

Figure 1 Daily temperature and rainfall during the experimental period.

Field Preparation

The experimental field was first cleared and then ploughed twice. Secondary and tertiary tillage operations were carried out to obtain a fine tilth of soil before sowing.

Fertilizer Application

The blanket recommended dose of the fertilizer for wheat cultivation in the hill region i.e., 6 mt ha^{-1} FYM and 100:40:40 N: P_2O_5:K_2O kg ha^{-1} was applied to meet the crop nutrient demand. Urea, DAP, and MoP were the fertilizer sources of the primary nutrients supplied to the crops. A full dose of P_2O_5, K_2O, and half dose of nitrogen was applied as basal dose at the time of final land preparation before sowing. The remaining half dose of nitrogen was applied in two splits, first at the active tillering stage and second at the booting stage (50% plant population) of the crop.

Seeds and Sowing

Pure breeder seeds of the WK3026 variety of wheat were sown continuously at the spacing of 20 cm between the rows and with seed rate as per treatment. The sowing of seeds was done manually on four different dates at an interval of fifteen days starting from the 12^{th} of November, 2020.

Weeding and Irrigation

The crop-weed competition in the experimental field was checked by controlling the weed growth through manual or hand weeding. Weeding was done as per the need to make the field weed free. No chemical weedicides were used for checking the weed infestation. Irrigation was provided during the crown root initiation stage (CRI). The crop water requirement was fulfilled by rainwater on other critical stages and when short, external irrigation was provided.

Harvesting and Threshing

After the crop reached the harvest maturity stage showing different maturity indices (brittle/distorted awn, yellowing of stem, dry flag leaf, etc.), manual harvesting was done with the help of sickles. The harvested plants were left in the field to sundry. A pedal thresher was used for threshing and winnowing was done for cleaning the seeds.

Observations Taken

Leaf area index (LAI)

The leaf area measurement was done manually by measuring the average length and breadth of leaves of five randomly selected plants from the destructive sampling row. The length was measured directly with scale and for breadth, the leaf was folded thrice to divide the leaf into four equal halves, and the three breadths measured from folded points were worked out to find an average breadth of the leaf and then used for leaf area calculation. The leaf area obtained was then used to calculate the LAI using the following formula.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Where, both the leaf area and ground area were worked out in cm^2.

Days to heading

The number of days taken from the day of sowing to the day to reach the heading stage (full exertion of the spike) in 50% plant population within a plot was noted.

Days to flowering

The number of days taken from the day of sowing to the day 50% plant population within a plot reached the flowering stage was noted.

Days to physiological maturity

The days to 50% maturity from the days of sowing within a plot were noted. It is the number of days taken by 50% plant population within a plot to reach the physiological maturity stage which is indicated by the maturity indices like yellowing and drying of flag leaf, yellowing of stem, yellowing of the spikes, etc.

Effective number of tillers

The effective number of tillers was determined by counting the number of tillers in an entire row in each plot before harvesting. This number was later worked to calculate the number of effective tillers per square meter.

Spike length

Ten spikes were randomly selected from the net plot and the length (cm) was measured from the base to the tip of the spike excluding the awn with the help of a measuring scale.

Number of grains per spike

The ten spikes that were randomly selected for measuring the spike length were used for the determination of the number of grains per spike. The grains were first detached/separated from the spike and then counted for ease of work.

Thousand-grain weight

A thousand grains were counted from randomly separated grain yield from the yield of the net plot and weighed (in grams) with the help of electronic digital balance.

Grain yield and straw yield

Grain yield and straw yield were taken at harvesting from the net plot. The crop was dried, threshed, sun-dried; cleaned, and the final weight of both straw and grain (before drying and after drying) was taken. The grain yield per hectare was calculated for each treatment. An automatic moisture recording meter was used for accessing the moisture percentage of grains.

$$\text{GYM} = \frac{(100 - \text{MC}) \times \text{plot yield (kg)} \times 10000}{(100 - 14) \times \text{net plot area}}$$

Where GYM is Grain yield (kg per ha) at 14% moisture and MC is the moisture content of grains in percentage. The straw yield was also recorded from the net plot and then later worked into a hectare.

Harvest Index

The Harvest index (HI) was calculated by dividing the grain yield by the biological yield.

$$\text{HI} = \frac{\text{Grain yield}}{(\text{Grain yield} + \text{Straw yield})}$$

Statistical analysis

The complete recorded data were entered in Microsoft Excel and further subjected to analysis of variance. The statistical package GENSTAT was used for the analysis of the data. Duncan's Multiple Range Test (DMRT) was used for mean comparison at a 0.05 level of significance.

Results

Leaf Area Index

The mean leaf area index was found to increase from 45 days after sowing (DAS) to 105 DAS and decrease thereafter (Table 3). The leaf area index was found significantly different among different sowing dates at different stages of crop growth except at 90 DAS. Within sowing dates, the LAI of wheat that was sown on Nov 12 and Nov 27 were statistically the same but were statistically different from the LAI of the wheat plants sown on Dec 12 and Dec 27. LAI of the wheat plants that were sown on Dec 27 was found lowest throughout the crop growth period. Similarly, among seed rates, there was no significant difference in LAI in the initial stages of crop growth. However, in the later stages, LAI was significantly affected by seed rate. The LAI of wheat crop sown at a seed rate of 160 kg ha^{-1} was found highest and that of wheat sown at a seed rate of 100 kg ha^{-1} was found lowest in the later stages. No interaction was found among seed rates and sowing dates for LAI.

Days to 50% Heading

The mean days to 50% heading was found to be 108 days (Table 4). The date of sowing had a significant effect on days to 50 % heading but no significant influence was observed on days to 50 % heading due to seed rate. The experiment showed that days to 50 % heading in wheat was shortened due to delays in the sowing of the crop. Wheat that was sown on November 12 took the highest (116 days) number of days to reach the 50% heading stage and the number of days gradually decreased with the subsequent delay in sowing. Wheat that was sown on December 27 reached 50 % maturity in the shortest (97 days) period. There was no significant impact of seed rates on days to the heading of wheat i.e., the effect of varied seed rates on days to heading was statistically the same. No interaction was observed among the treatments.

Table 3. Leaf area index as influenced by date of sowing and seed rates at different stages of wheat growth.

Treatments	Leaf Area Index (mean ± SE)						
	45DAS	60DAS	75DAS	90DAS	105DAS	120DAS	135DAS
Sowing Date (A)							
Nov 12	1.3±0.2^{a}	2.8±0.3^{a}	3.2±0.3^{a}	4.3±0.3	4.5±0.2^{ab}	5.5±0.6^{a}	4.9±0.4^{a}
Nov 27	0.8±0.1^{ab}	1.9±0.2^{ab}	3.3±0.3^{a}	5.0±0.5	5.2±0.3^{a}	6.6±0.7^{a}	4.8±0.5^{a}
Dec 12	0.4±0.0^{b}	1.2±0.2^{b}	1.9±0.3^{b}	3.7±0.5	4.0±0.3^{b}	2.4±0.2^{b}	1.8±0.2^{b}
Dec 27	0.5±0.1^{b}	1.1±0.1^{b}	1.7±0.3^{b}	3.3±0.6	2.7±0.2^{c}	1.5±0.2^{b}	0.5±0.1^{b}
SEM (±)	0.1448	0.3506	0.342	0.726	0.151	0.494	0.6523
LSD (<0.05)	0.5012	1.2133	1.182	NS	0.524	1.710	2.2574
Seed Rate (B)							
100 kg ha^{-1}	0.7±0.2	1.6±0.3	1.8±0.3^{b}	3.6±0.5	3.4±0.3^{b}	2.9±0.4^{b}	2.6±0.6^{b}
120 kg ha^{-1}	0.8±0.2	1.6±0.2	2.3±0.4^{ab}	3.6±0.5	4.1±0.4^{ab}	4.2±0.8^{a}	3.0±0.6^{ab}
140 kg ha^{-1}	0.8±0.2	1.9±0.2	2.9±0.3^{a}	4.8±0.6	4.2±0.3^{ab}	4.7±1.0^{a}	3.0±0.6^{ab}
160 kg ha^{-1}	0.8±0.1	1.9±0.4	2.9±0.4^{a}	4.3±0.4	4.8±0.4^{a}	4.2±0.8^{a}	3.4±0.8^{a}
SEM (±)	0.1157	0.1787	0.267	0.404	0.201	0.381	0.1995
LSD (<0.05)	NS	NS	0.781	NS	0.588	1.113	0.5823
A*B	NS	NS	NS	NS	NS	NS	NS
CV%	52.7	35.9	36.8	34.4	17.0	33.0	22.9
Grand Mean	0.76	1.72	2.52	4.07	4.10	4.00	3.01

Means followed by a common letter (s) are not significantly different from each other based on DMRT at a 5% level of significance. SEM= standard error of means, LSD= least significant difference, CV= coefficient of variance, and NS= non-significant.

Table 4. Phenological observations as influenced by date of sowing and seed rate in growth of wheat.

Treatments	Days to 50 % heading (mean ± SE)	Days to 50% flowering (mean ± SE)	Days to 50% maturity (mean ± SE)
Sowing Date (A)			
Nov 12	116±0.4^{a}	123±0.5^{a}	179±0.2^{a}
Nov 27	113±0.2^{b}	116±0.2^{b}	168±0.2^{b}
Dec 12	105±0.4^{c}	109±0.3^{c}	157±0.2^{c}
Dec 27	97±0.4^{d}	101±0.4^{d}	145±0.1^{d}
SEM (±)	0.27	0.24	0.21
LSD (<0.05)	0.95	0.84	0.72
Sowing Rate (B)			
100 kg ha^{-1}	108±2.0	112±2.3	162±3.9
120 kg ha^{-1}	108±2.3	113±2.7	162±3.8
140 kg ha^{-1}	107±2.1	112±2.5	162±4.0
160 kg ha^{-1}	108±2.3	112±2.5	162±3.8
SEM	0.37	0.34	0.15
LSD (<0.05)	NS	NS	NS
A*B	NS	NS	NS
CV%	1.2	1.1	0.3
Grand mean	108	112	162

Means followed by a common letter (s) are not significantly different from each other based on DMRT at a 5% level of significance. SEM= standard error of means, LSD= least significant difference, CV= coefficient of variance, and NS= non-significant.

Table 5. Yield and yield attributes as influenced by seed rates and sowing dates on wheat.

Treatments	Effective Tillers/m^{2}	Spike Length (cm)	Grains/Spike	Grain yield (Mt ha^{-1})	SDM (Mt ha^{-1})	TGW (g)
Sowing Date (A)						
Nov 12	477.6±16.1^{b}	9.0±0.0^{b}	39.5±0.9^{ab}	6.5±0.2^{b}	8.9±0.3^{a}	46.3±0.5^{a}
Nov 27	635.6±40.8^{a}	9.6±0.1^{a}	41.5±0.5^{a}	7.6±0.2^{a}	9.6±0.3^{a}	45.8±0.3^{a}
Dec 12	498.5±15.7^{b}	9.0±0.0^{b}	36.8±0.8^{bc}	5.3±0.1^{c}	7.4±0.2^{b}	43.8±0.8^{b}
Dec 27	382.3±18.8^{c}	8.8±0.1^{b}	35.2±0.4^{c}	5.2±0.1^{c}	4.9±0.2^{c}	41.2±0.8^{c}
SEM (±)	27.3	0.14	0.98	0.29	0.35	0.42
LSD (<0.05)	94.6	0.49	3.40	1.01	1.21	1.45
Seed Rate kg ha^{-1} (B)						
100 kg ha^{-1}	457.6±36.6	9.1±0.1	37.2±0.9	6.1±0.4	7.6±0.7	45.6±0.9
120 kg ha^{-1}	500.4±35.3	9.1±0.1	38.7±1.1	6.2±0.4	7.8±0.5	44.1±0.7
140 kg ha^{-1}	526.0±31.7	9.1±0.1	38.5±1.0	6.2±0.3	7.4±0.6	43.7±0.7
160 kg ha^{-1}	510.0±40.7	9.1±0.1	38.6±1.0	6.1±0.3	7.9±0.6	43.7±1.0
SEM (±)	28.3	0.03	0.50	0.16	0.25	0.64
LSD (<0.05)	NS	NS	NS	NS	NS	NS
A*B	NS	NS	NS	NS	NS	NS
CV%	19.6	1.2	4.5	9.0	11.3	5.0
Grand mean	499	9.1	38.25	6.13	7.69	44.27

Means followed by a common letter (s) are not significantly different from each other based on DMRT at a 5% level of significance. SDM= Straw dry matter, TGW= Thousand grain weight, SEM= standard error of means, LSD= least significant difference, CV= coefficient of variance, and NS= non-significant.

Days to 50% Flowering

In the experiment, the mean days to 50 % flowering was found to be 112 days (Table 4). The date of sowing had a significant effect on days to 50 % flowering but no significant influence was observed on days to 50 % flowering due to seed rate. The days to reach 50 % flowering was observed highest (123 days) in wheat sown on November 12 and this period decreased with the subsequent delay in sowing. Wheat sown on December 27 reached 50 % flowering stage in the shortest period (101 days). The effect of varied seed rates on days to reach 50 % flowering stage was statistically found to be the same. No any sort of statistical interaction was observed among the treatments.

Days to 50% Maturity

In the experiment, the mean days to reach 50 % maturity was found to be 162 days (Table 4). A significant influence on days to 50 % maturity was observed due to variation in sowing dates but there was no significant effect of varied seed rate on it. The number of days to reach 50 % maturity was found highest (179 days) in the wheat that was sown on November 12 and this period subsequently decreased over delay in sowing dates. Wheat that was shown on December 27 reached 50 % maturity in the shortest period (145 days). The effect of varied seed rates on days to reach the 50 % maturity stage was statistically found to be the same. No any sort of statistical interaction was observed among the treatments.

Effective Tillers/m²

In the experiment, the mean effective number of tillers per square meter was found to be 499 (Table 5). It was observed that the effective number of tillers was significantly influenced by the date of sowing but there was no significant influence on the effective number of tillers due to varying seed rates. No interaction was observed between the two treatments. As per Table 5, the highest number of effective tillers per square meter (635.6) was observed in wheat sown on November 27. The effective number of tillers per square meter of wheat grown on November 12 and December 12 was statistically the same. Wheat that was sown on December 27 had the least number of effective tillers per square meter (382.3).

Spike Length

The mean spike length of wheat in the experiment was found to be 9.1 cm (Table 5). It was observed that the spike length of wheat was influenced significantly by the date of sowing but there was no significant influence of varied seed rate on the length of the spike. Wheat sown on November 27 had the highest length of the spike (9.56 cm) which was significantly different from the length of the spike of wheat sown on other dates. Wheat sown on December 27 had the least (8.77 cm) length of the spike. It showed that both early and late planting reduced the length of the spike. No interaction between the treatments was observed.

Number of grains per spike

In the experiment, it was found that the mean grains per spike were 38.25 (Table 5). The grains per spike were also significantly influenced by the date of sowing but not by the varying seed rates. Wheat sown on November 27 had the highest (41.49) grains per spike which was statistically similar to wheat sown on November 12 (39.49) but significantly differed from the values of wheat sown late in the season. The grains per spike in the wheat that was sown on December 27 had the minimum value as per the results of the experiment. Interaction among the treatments for grains per spike was not observed in the experiment.

Grain Yield (t ha⁻¹)

The mean grain yield of wheat in the experiment was found to be 6.13 t ha^{-1} (Table 5). It was observed that the grain yield of wheat was significantly influenced by the date of sowing but no influence was observed due to a change in seed rate statistically. No interaction between the treatments was observed for the grain yield of wheat. As per the results, wheat sown on November 27 had a maximum grain yield (7.59 t ha^{-1}) that was statistically different from the yield of wheat sown on other dates. This value was followed by the wheat sown on November 12 i.e., 6.45 t ha^{-1} and the wheat that was sown on December 27 had the least grain yield of 5.17 t ha^{-1}. Although the grain yield was not significantly influenced by varied seed rates, it was observed that grain yield was maximum under wheat sown at a seed rate of 120 kg ha^{-1} and minimum under wheat sown at a seed rate of 160 kg ha^{-1}.

Straw Yield (t ha⁻¹)

The mean straw yield in the experiment was 7.69 t ha^{-1} (Table 5). It was observed that the date of sowing had a significant influence on the straw yield but no significant difference was observed in the yield of straw due to changing seed rates. The straw yield of wheat that was sown on November 27 had a maximum value (9.58 t ha^{-1}) which was statistically similar to the straw yield of wheat sown on November 12 (8.88 t ha^{-1}) but significantly differed in the yield of straw sown later in the season. The straw yield of wheat sown on December 27 was found minimum i.e., 4.95 tons ha^{-1}. Although the straw yield was not significantly influenced by seed rates, the maximum yield of straw was observed under the seed rate of 160 kg ha^{-1}. The interaction between the treatments was not observed for the yield of straw in the experiment.

Thousand Grain Weight (g)

The mean thousand grains weight in the experiment was found to be 44.27 g (Table 5). A thousand grains' weight was also influenced significantly by the date of sowing but there was no significant influence due to seed rate on it. The thousand-grain weight was observed maximum in the wheat that was sown on November 12 (46.26 g) which was statistically similar to the thousand grains weight of the wheat that was sown on November 27 (45.84 g) but significantly differed in values in the wheat sown later on the season. Thousand-grain weight of wheat sown on December 27 was observed as a minimum (41.19 g). Although seed rate had no significant influence on thousand-grain weight, the highest value (45.58 g) was observed in the wheat sown at the rate of 100 kg ha^{-1}.

Harvest Index

In the experiment, the mean harvest index of the wheat crop was observed to be 0.45 (Table 6). It was found that the harvest index was significantly influenced by the date of sowing but no significant difference was found due to the seed rates. The Harvest index was statistically the same for varied seed rates. However, as per the results harvest index was found maximum in the wheat that was sown on December 27 (0.51) which significantly differed from the values obtained from the wheat sown on other dates. Wheat sown on December 12 and November 12 had the lowest harvest index (0.42). No interaction was observed between the treatments for the harvest index of the crop.

Discussion

Leaf Area Index

Duary & Yaduraju, (2006) revealed similar outcomes in their experiment except for 60 DAS in the second year, where it was not substantially different, the mid-November sown crop had a higher leaf area index than the mid-December sown crop and also at all phases, the leaf area index at 150 kg ha^{-1} seed rate was at its highest and greatly outperformed the 100 kg ha^{-1} seed rate. Tahir et al. (2019) also reported that more LAI was recorded with an increase in seed rates and in the case of sowing dates LAI decreased with late planting. The higher LAI of wheat sown in November was due to favorable weather conditions that increased the vegetative period and the lower LAI of December sown wheat could be due to lower temperatures during December and the late sown crop received less solar radiation at the critical growth stages (Tahir et al., 2019; Hussain et al., 2012a). Higher LAI in plants sown on high seed rate could be due to higher plant density per unit area that increased the percentage of light intercepted.

Table 6. Harvest index of wheat as influenced by date of sowing and seed rates.

Treatments	Harvest index (mean ± SE)
Sowing date (A)	
Nov 12	0.42±0.01^{b}
Nov 27	0.44±0.01^{b}
Dec 12	0.42±0.01^{b}
Dec 27	0.51±0.01^{a}
SEM (±)	0.02
LSD (<0.05)	0.06
Seed rate (B)	
100 kg ha^{-1}	0.45±0.02
120 kg ha^{-1}	0.44±0.01
140 kg ha^{-1}	0.46±0.01
160 kg ha^{-1}	0.44±0.01
SEM (±)	0.01
LSD (<0.05)	NS
A*B	NS
CV%	6.8
Grand mean	0.45

Means followed by a common letter (s) are not significantly different from each other based on DMRT at a 5% level of significance. SEM= standard error of means, LSD= least significant difference, CV= coefficient of variance, and NS= non-significant.

Days to 50 % Heading

Our results of days to 50% heading are in line with the findings of Hamid & Muhammad (2000) which showed that with a delay in sowing from 1st November to 20th December there was a corresponding decrease in the number of days to 50% heading and maturity. Also, both days to 50% heading and maturity were not significantly affected by seed rates. Khokhar et al. (2010) also reported that wheat sown in November took around 76-78 days for heading, providing more time compared to mid-December sowing which resulted in a shorter period of 70-69 days.

Days to 50% Flowering

Our findings regarding the time taken for 50% flowering are in line with Shazma et al. (2015) research. They observed that wheat planted on October 29th took more days (146) to reach anthesis, while the plot sown on December 10th exhibited a shorter period (109) to anthesis. The impact of seed rate on anthesis days, however, demonstrated inconsistency. Similar results were reported by Tahir et al. (2019), who noted that delayed sowing led to a reduction in days to anthesis. Notably, wheat sown on November 10th displayed the highest number of days to anthesis, in contrast to December 25th sowing which showed the shortest duration to anthesis.

Days to 50 % Maturity

The results of days to 50% maturity are in line with the findings of Tahir et al. (2019) who reported that the days to maturity were found higher in the wheat sown on November 10 and it gradually decreased with delay in sowing and was found least (121 days) on wheat sown on 25th of December. When wheat planting was delayed from 16 October to 15 March, there was a gradual shortening of the lifetime of the crop as higher temperatures enhanced crop processes over those at normal temperatures (Hakim et al., 2012).

Effective Tillers

The effective number of tillers was significantly affected due to the change in the date of sowing but had no significant impact on it due to varying seed rates. Also, no interaction was observed among the treatments for the effective number of tillers (Table 5). Akhtar et al. (2006) & Shah et al. (2006) found that the number of effective tillers was reduced by delayed sowing. Jan, Hamid & Muhammad (2000) also reported that productive tillers per square meter decreased with delay in sowing and the effect of seed rates on effective tillers per square meter was not significant. High tillers in early sowing may be due to a prolonged period for crop growth and temperature changes with delay in sowing cause low productive tillers in late-sown wheat. The temperature of the shoot meristem is linearly related to the rate of leaf initiation and appearance on the main column (Ong & Baker, 1985).

Spike Length

The length of the spike in wheat has a direct impact on its yield, considering its relationship with the grains per spike (Shahzad et al., 2007). In a study by Baloch et al. (2010), it was observed that delayed sowing led to a reduction in spike length. This emphasizes the significance of appropriate sowing timing for optimizing wheat yield potential. Spike length was not significantly affected by seed rate or its interaction with sowing time. According to Waraich et al. (1981), early planting led to a stronger spike in growth because of a longer growing season. Spike length was not significantly affected by seed rate or its interaction with sowing time, although on October 25th, with 100 and 175 kg of seed ha^{-1}, a larger spike length of 10.2 cm was observed. Farooq et al. (2016) reported that in early planting, spike length increased due to the longer time available for a spike to develop.

Number of grains per spike

Our results of grains/spike are in line with Tahir et al. (2019) who reported that higher grains per spike were observed at the 25th November sowing date, which was statistically similar to the 10th November sowing date. Fewer grains per spike were found on the last sowing date i.e., the 25th of December. In the study by Shazma et al. (2015), it was observed that there was a consistent decrease in the number of grains per spike with the delay in sowing dates, and the impact of seed rate on grains per spike was unpredictable. Similarly, Jan, Hamid & Muhammad (2000) found that the highest number of grains per spike was recorded in plots sown on November 20th, with lower counts in plots sown both earlier and later than this date. This corresponds with the findings of Yajam et al. (2013), where early planting was associated with a higher number of grains per spike.

Grain Yield

Shahzad et al. (2007) also obtained lower grain yield with delay in sowing due to a shorter duration of growth and development. Ebrahimi & Dastan, (2016) revealed that grain yield was significantly affected by different sowing dates while seed rate and interaction were non-significant. Baloch et al. (2010) also reported significant effects (P<0.05) of different sowing times, whereas, seed rate differed non-significantly for the grain yield. The higher grain yield was obtained from October 25 and November 10 planting dates while December 25 planting date produced the lowest grain yield. Akmal et al. (2011); Baloch et al. (2012) & Poudel et al. (2020) reported significantly higher yields in early sown wheat compared to late sown wheat because of maximum partitioning of photosynthate to grain. According to Ahmad et al. (2018), an increase in temperature reduces yield since it accelerates growth and shortens the growing season.

Straw Yield

Although the impact of seed rate on straw yield was non-significant, the straw yield was observed maximum with wheat sown at maximum seed rate. The straw yield is reflected by growth parameters like the total number of tillers, leaf area, and plant height. Shazma et al. (2015) reported a biological yield maximum in early sown plots. Marasini et al. (2016) reported that the straw yield was significantly higher in wheat sown on November 29. Tahir et al. (2009) also reported similar results in straw yield in their experiment where the straw yield decreased with late planting of the crop. This might also be due to the shortening of the vegetative period of the late sown crop.

Thousand Grains Weight

Our results of thousand grains weight are in line with the findings of Shahzad et al. (2007) who also observed that earlier sowing resulted in better development of the grain due to a longer growing period. This is also supported by the findings of Baloch et al. (2010) where the results are similar to this experiment. Although seed rates had no significant impact on thousand-grain weight, increasing seed rates did not show a positive effect on grain weight which may be due to bulk plant density on account of high seed rates that eventually decreased seed weight. Due to a shorter grain filling phase caused by higher temperature during the reproductive period of late-sown wheat, grain weight was reduced which ultimately decreased the production (Hussain et al., 2012b; Ahmad et al., 2018).

Harvest Index

The results in Table 6 show that the harvest index in wheat was significantly influenced by the date of sowing but no significant influence of seed rate on it was observed. The harvest index of wheat sown on December 27 was observed as maximum and that of wheat sown on other early dates was statistically the same. The results are contrary to the findings of Thapa et al. (2020) where the harvest index was low for late-planted conditions (14^{th} December) than for timely sown (14^{th} November). But the results in this experiment were supported by the findings of Madhu et al. (2018) where the highest harvest index (31.66%) was recorded on 30 December sowing and the lowest (27.70%) was found on 15 November sowing. Farooq et al. (2016) reported similar results where the harvest index was maximum on wheat sown in December and a lower harvest index was observed on earlier sown wheat with the lowest in wheat sown on 25^{th} October. Early planting may have had the lowest H.I. because of taller plants' larger biomass, more tillers per square meter, and dense population, all of which reduced the ratio of economic output.

Conclusion

The impact of the varied sowing date was clearly observed on yield and yield attributing characters of wheat where the best results on these were observed in wheat sown on November 27 as compared to other dates. While, seed rate had no significant impact on yield and attributing characters, though, maximum grain yield was observed on wheat sown under the rate of 120 kg ha^{-1}. Thus, early planting of wheat on November 27 at a seed rate of 100 kg ha^{-1} is better for wheat cultivators in mid hills having the conditions of Lalitpur, Nepal.

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