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Response of Micronutrients on Growth and Yield of Wheat Under Late Seeding Heat Stress Condition

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University of Rajshahi

Ph.D.
THESIS

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SUBMITTED BY

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OF

DOCTOR OF PHILOSOPHY

IN THE

DEPARTMENT OF AGRONOMY AND

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BY

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RAJSHAHI-6205, BANGLADESH

April, 2021

DEDICATED TO

My Mother

Who always gives me inspiration to

fight against obstacles in life

&

My Father

Who has created my interest on research.

DECLARATION

I, hereby declare that the entire work submitted as thesis entitled "RESPONSE OF MICRONUTRIENTS ON GROWTH AND YIELD OF WHEAT UNDER LATE SEEDING HEAT STRESS CONDITION" to the University of Rajshahi, Bangladesh for the degree of Doctor of Philosophy, is based on my original investigation.

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CERTIFICATE

*We hereby certify that the research work entitled **"RESPONSE OF MICRONUTRIENTS ON GROWTH AND YIELD OF WHEAT UNDER LATE SEEDING HEAT STRESS CONDITION"** submitted for the degree of **Doctor of Philosophy** in the subject of Agronomy is a research work carried out by **Maria Marzan** under our supervision in the University of Rajshahi, Rajshahi-6205, Bangladesh. The results of the investigation, which embodied here are original and have not been submitted before in substance for any other degree of this or any other university.*

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I wish her every success in her academic and personal endeavors.

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ABBREVIATIONS AND ACRONYMS

Abbreviation		**Full word (s)**
%	=	Percent
/	=	Per
^0C	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research.
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
CGR	=	Crop Growth Rate
CRI	=	Crown Root Initiation
cm	=	centimeter
CV	=	Coefficient of Variance
d^{-1}	=	Per day
DAA	=	Days After Anthesis
DAE	=	Department of Agricultural Extension
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
e.g.	=	Exampli gratia (= for example).
etc.	=	etcetra.

et.al.	=	etalia (= and the others).
FAO	=	Food and Agriculture Organization
Fig.	=	Figure.
g	=	Gram(s)
GDP	=	Gross Domestic Product
gm^{-2}	=	Gram Per Meter Square
$gm^{-2}day^{-1}$	=	Gram Per Meter Square Per Day
ha	=	Hectare
ha^{-1}	=	Per hectare
i.e.	=	idest (= that is).
Kg	=	Kilogram.
kg ha^{-1}	=	Kilogram per hectare
LAI	=	Leaf Area Index
LAR	=	Leaf Area Ratio
LS	=	Level of Significance
LSD	=	Least Significant Difference
LWR	=	Leaf Weight Ratio
m	=	Meter
m^2	=	Square Meter
m^{-2}	=	Per square metre
ml	=	Mililiter
mm	=	Millimeter
MoP	=	Muriate of Potash
MT	=	Metric tons.
nm	=	Nanometer.
NAR	=	Net Assimilation Rate

No.	=	Number.
NS	=	Non-Significant
p^H	=	Negative logarithm of hydrogen ion (H^+) concentration
ppm	=	Parts Per Million
RGR	=	Relative Growth Rate
RLGR	=	Relative Leaf Growth Rate
SLA	=	Specific Leaf Area
SRDI	=	Soil Resource Development Institute
t	=	Ton
t ha^{-1}	=	ton per hectare
T	=	Tillering
TDM	=	Total Dry Matter
TSP	=	Triple Super Phosphate
TSS	=	Total Soluble Solids.
viz.	=	Vizard (namely)/ that is to say.
w	=	Weight

ABSTRACT

Cereal and its derived products have a crucial importance worldwide. Baking industries extensively use wheat flour and also important source of various nutrient components. Therefore, this investigation is intended to study and determine growth, yield and physiochemical properties of wheat varieties. Heat stress is a worldwide problem, constraining global crop production seriously. The experiment was conducted to study the response of micronutrients on growth and yield of wheat under late seeding heat stress condition at the Regional Wheat Research Centre (RWRC), Rajshahi during the Rabi season from November 2015 to April 2016 and November 2017 to April 2018. A split-split plot design was adopted with three replications. Two wheat varieties BARI Gom 26 and BARI Gom 28 were used as test crop, three seeding dates one was optimum and other two were late condition (25th November, 10th December and 25th December) were applied as heat stress condition and four micro-nutrients levels (absolute control, 1.25 kg B ha^{-1}, 5.30 kg Zn ha^{-1} and 1.25 kg B ha^{-1} + 5.30 kg Zn ha^{-1}) were used to conduct this experiment. The study revealed that the crop sown on the 25th November gave most of the highest growth, yield components, yield and finally produced the highest nutrient parameters from both the years. Heat stress late sown condition caused significant reductions in growth and yield of both wheat varieties. It was evident from the results that micro-nutrients have significant effect on growth parameters. Total Dry Matter (TDM) increased with the increase of age of plant. Leaf Area Index (LAI) increased slowly at the early stage of crop growth then rapidly increased at vegetative stage and then it decline. Crop Growth Rate (CGR) and Net-Assimilation Rate (NAR) also had the similar results. Relative Growth Rate (RGR) was also found

maximum at crown root initiation to tillering stage and then declined with increasing in plant growth stage. Leaf Area Ratio (LAR) declined in the successive growth stage and it reached the lowest at maturity stage in both the years. However, the highest grain yield was obtained from the treatment M_3 (1.25 kg B ha^{-1} + 5.30 kg Zn ha^{-1}). The results revealed that BARI Gom 28 produced the highest grain yield with M_3 (1.25 kg B ha^{-1} + 5.30 kg Zn ha^{-1}). In contrast, the shortest plant and minimum grain yield being recorded from the control treatment. In comparison among of two wheat varieties with the response of different levels of micro-nutrients under late seeding heat stress condition demonstrated that BARI Gom 28 gave the highest performance (yield 4.99 and 4.63 t ha^{-1}) than BARI Gom 26 (yield 2.40 and 1.60 t ha^{-1}) in both the two years among most of the parameters. The results of the experiment also revealed the bio-chemical composition of wheat grain. Each sample has been counted in 100 g of grain. Heat stress also decreased all the nutrient parameters except protein and ash content. The BARI Gom 28 had the highest amount of protein, carbohydrate, starch, p^H, ash, Ca, and P with the treatment M_3 (1.25 kg B ha^{-1} + 5.30 kg Zn ha^{-1}) whereas BARI Gom 26 had highest TSS, Fe and Zn. Results showed that both the wheat variety could be used to make various type of brand wheat flour for baking products. The overall results indicate that micronutrient levels M_3 (1.25 kg B ha^{-1} + 5.30 kg Zn ha^{-1}) was better in variety BARI Gom 28 than BARI Gom 26 for growth, yield and yield contributing characters as well as nutrient parameters under late sown heat stress tolerance in AEZ-11. The data obtained from this comparative study will help in the development of suitable growth, yield and nutrient profile of wheat grain under late sown heat stress condition.

CHAPTER 1

INTRODUCTION

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INTRODUCTION

The agricultural sector plays a very remarkable role in the Bangladesh economy. Agriculture accounts for about 20% of the country's Gross Domestic Product (GDP). The common wheat (*Triticum aestivum* L.) is a hexaploid (6n=42) cereal plant of the genus *Triticum*, especially, *Triticum aestivum*, of the family Graminae. According to the fifth of humanity's food, wheat (*Triticum aestivum L.*) is third after rice (BBS, 2020) as a source of calories in the diets of consumers in developing countries and the First as a source of protein (Braun *et al.* 2010) and 9% of the daily caloric intake in Bangladesh (Tama's *et al.* 2009). Wheat (*Triticum aestivum* L.) covers the more earth's surface area than any other food crop and its production is the third largest cereal production in the world, after maize and rice and identified wheat as the key to the emergence of urban societies for millennia FAO (2018). 699.4 million metric tons estimated in 2011-2012 was the global wheat production (FAO, 2012). The average yield of wheat in Bangladesh is 3.62 t ha^{-1} (BBS, 2020), much lower than other wheat growing counties around the world as well as the average growth and yield of wheat is very low compared to the average growth and yield of Newzealand, Nethrlands, Ecuador and France (8.9, 8.6, 8.0 and 7.6 t ha^{-1} respectively) (FAO, 2018) whereas the annual production of wheat in 2012-2013 was 8.49 lakh tons obtained from 3.94 lakh ha. of land with an average yield of 2.15 t ha^{-1} (BBS, 2013). The total area are about 4,29,607 ha and production of wheat 13,02,998 metric tons in Bangladesh (BBS, 2020). As Bangladesh is a density populated country and total land area under crop production has been decreasing day by day to accommodate the rapidly increasing population. On the other hand the amount of rice production is not enough for feeding a large number of its hungry people in our country. As a result the total production of cereal grain is decreasing and the country is suffering from food deficiency. Wheat production need to be increased by 77% in the developing countries to accomplish the future demands FAO estimated for the world would require additional 198 million tons of wheat by 2050. CIMMYT predicted that demand for wheat in the developing world is projected to increase 60% by 2050 from now (CIMMYT, 2018). The extension of wheat cultivation during the rabi season is one of the feasible approaches in solving the food problem of Bangladesh. There is a limitation in increasing cultivable land therefore, methods to increase yield have to be explored.

The growth and yield of wheat can be augmented with the use of high yielding varieties and suitable agronomic practices. The yield of wheat in the farmer's field is much lower than that in the research farm (Anonymous, 2008). Variety is very important in case of producing high yield of wheat. Difference has found with varieties when the development process of wheat plants under a given agro-climatic condition (Anonymous, 2008). Wheat Research Centre (WRC) and Bangladesh Agricultural Research Institute (BARI) have released 33 improved wheat varieties but many of them were not adequately adopted by farmers. There can be a range of reasons including inadequate knowledge, lack of specifically adapted varieties and inadequate extension efforts.

Generally, through milling process of whole wheat kernel wheat flour is produced to prepare biscuit, cake, puffins, toast, bread, baby formulates, noodles, confectionary, breakfast and soup making wheat flour is used (Kumar *et al.* 2011). Moreover, the wheat is additionally utilized for production of alcoholic and other drinks, as well as cattle food production (Husejin Keran *et al.* 2009). Wheat bran is a good source of dietary fiber which helping in the prevention and treatment of some digestive disorders. Globally, Wheat makes as larger contribution of vegetable proteins and calories to man than all other foods or cereal crops i.e., maize (corn) or rice. Wheat is the most important source of concentrated carbohydrate for human being and it contains considerable amount of protein, minerals and vitamins. According to USDA (2014) one cup whole wheat grain contains 33% Protein, 29% Carbohydrate and 5% Fat and currently about 65% of wheat crop is used for food, 17% for animal feed and 12% in industrial applications. The wheat flour quality can be estimated by different parameters (Hruskova and Famera 2003). Therefore, the purpose of this study was to investigate the various quality parameter of wheat grain.

Climate of the globe is changing day by day. Various environmental stresses influences plant growth and development and that have attained a serious concern in the context of possible climate change. High temperature induced heat stress is expressed as the rise in air temperature, that beyond a threshold level for a period sufficient to cause injury or irremediable damage of crop plants in general (Teixeira *et al.* 2013). The harmful effects of climate change are challenging the food security of the world on crop production. By increasing temperature wheat production will be impacted more (Tripathi *et al.* 2016). Environmental change could firmly influence wheat production, representing 21% of food and 200 million hectares of farmland worldwide (Ortiz *et al.* 2008).

The optimum time for wheat seed sowing is from 15-30 November. Depending on the weather November and ends in late December is the optimum sowing time of wheat in Bangladesh, topography and harvesting of the preceding crops (Haider 2007). Generally, the farmers of our country cultivate wheat after harvesting of T. Aman Rice. T. Aman Rice cultivation fully depends on natural rainfall. Due to adverse weather Farmers cannot plant T. Aman Rice timely, ultimately harvest in late. Most of the farmers sow seed in December, even in later. In Bangladesh average temperature lies under 22°C from November to February, then temperature rises drastically and lies above average 32°. Drastic reduction in yield of wheat has been recorded with the delay of sowing beyond optimum time (Ram *et al.* 2012). So, it is essential to find out the proper date of sowing of wheat taking into consideration of climatic condition and cropping pattern of Bangladesh to obtain the maximum yield.

The average daily temperature in Bangladesh has increased by 0.103°C per decade over the past four decades (Shahid 2010). The projections say that temperature of Bangladesh will continue to increase by 1°C by 2030, 1.4°C by 2050 and 2.4°C by 2100 due to global warming (IPCC 2007). In future the production of wheat will influence more adversely (Poulton and Rawson 2011). High temperature influences crops in various manners. Such impact varies relying upon the crops, cultivars, and phenological stages. Various models based on climate impact assessment of adaptation measures were approached by Reidsma *et al.* (2010). Deryng *et al.* (2014) considered as adaptive measures under extreme heat stress conditions was the selection of cultivars and changing seeding dates. However, in future the development of heat-tolerant wheat varieties is crucial in meeting the food security (Ortiz *et al.* 2008). Therefore, it is needed to explore the tolerant cultivars that will ensure higher grain yield under heat stress.

The growth of plants is determined by the fertility of soil which is an important factor. Soil fertility is determined by the presence or absence of macro and micronutrients. It is perceived that micronutrients play a pivotal role in the yield improvement (Rehm and Sims 2006). Although, micronutrients are required in trace amounts but their adequate supply improves nutrient availability and positively affect the cell physiology that is reflected in yield as well (Taiwo *et al*. 2001; Adediran *et al*. 2004). In spite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. High fertilizer responsive varieties express their full yield potential when trace elements are applied along with NPK fertilizers (Nataraja *et al.* 2006). Chaudry *et al.* (2007) stated that micronutrients (Zn, Fe, B) significantly increased the wheat yield over control when applied single or in combination with each other while Mandal *et al.* (2007) observed significant positive interaction between fertilizer treatments and physiological stages of wheat growth. Khan *et al*. (2006) reported that Cu, Fe, Mn and Zn contents of leaf, straw and grain of wheat increased with the application of mineral fertilizers. Ziaeian and Malakouti (2001) reported that total uptake of Zn, Cu, Fe and Mn, in grain and flag leaves was significantly increased. These micronutrients help in chlorophyll formation, nucleic acid, protein synthesis and play an active role in several enzymatic activities of photosynthesis as well as respiration (Reddy 2004). Their lack greatly influences the quantity and quality of plant products (Ahmadikhah *et al*. 2010). Micronutrient deficiency has become a major yield limiting factor that may either be primary, due to their low total contents or secondary, caused by soil factors that reduce their availability to plants (Sharma & Chaudhary 2007). In Bangladesh, nutrient stresses on soils are progressively increasing due to high cropping intensity with high yielding crop varieties, decreasing of organic matter from soil etc. So, need for micronutrient in soil is increasing, yet the proportion of different fertilizer used in the country is not quite balanced. Among different micronutrient elements, Zn and B are considered to be the most important in order to obtain optimum production in case of wheat. The deficiency of Zn and B is reported in some soils and crops of Bangladesh (Jahiruddin and Satter, 2010). Zinc is a basic part of various enzyme systems for energy production, protein synthesis and growth regulation. It likewise helps in the reproduction of plants. Plants exhibits poor growth, interveinal chlorosis and necrosis of lower leaves due to the deficiency of zinc. Older leaves get reddish or brownish spot and is reduction of seed production also occurring due to its deficiency. Deficiency of zinc in wheat has been reported from various parts of the world. Reports showed that 30% soil in the world exhibit Zinc deficiency to different extents (Cakmak *et al.* 2009) and more than two billion people cannot be supplied with sufficient Zinc. Zinc deficiencies are widely spread throughout Bangladesh, especially in the wheat field, deficiencies occurs in neutral and calcareous soils. Soil or foliar applications of Zn may also increase grain zinc concentration and thus contribute to grain nutrition. Boron application has both direct and indirect effects on wheat fertilization. The soils of Bangladesh in some areas are deficient in some micro elements and boron is one of them. Boron is essential for the development of root system, fruit setting and grain formation. The direct impact of boron is reflected by a close relationship between boron supply, pollen producing capacity of the anthers and the viability of pollen grains. Lack of Boron is accounted on some soils and crops. Cell wall formation is the primary function of boron so boron inadequate plant may be stunted. It may induce male sterility in wheat. The reason for the lowest grain yield in boron deprived plots might be the higher pollen infertility and lower grain filling as it plays very active role in both processes (Rashid *et al.* 2004). The overarching circumstance underscores the requirement for investigation whether micronutrient inadequacy is a causative factor for poor grain formation, grain yield and nutrient content of wheat. Thus the present study was conducted to assess the effect of micronutrients on the growth and yield of wheat.

The current investigation was under taken with the following objectives:

1. To observe the effect of late sown heat stress condition on the growth, yield and yield components of wheat cultivars.
2. To study the effect of different micronutrient levels on the growth and yield of wheat varieties.
3. To estimate the growth, yield and nutritional food value of wheat varieties under late sown heat stress condition with the application of micronutrients.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

This chapter presents a complete review of the study which have been done including Bangladesh and many other countries of the world with regards to the effect of different wheat variety, sowing time and micronutrients (especially Zn and B) on growth and yield as well as nutrient content of wheat. Heat stress affects the growth and grain yield in wheat. An emphasis has been given to the literature that has been published in the last two decades.

2.1 Origin of wheat

Wheat (Triticum aestivum *L*) is an annual plant that belongs to grass family graminae under division of Magnoliophyta. It is thought to have originated on the Eurasian continent that's mean Turkey. At starting point man spread it throughout the world, including China and Central Europe. Wheat is one of the earliest domesticated crop plants in the pre-Pottery Neolithic Near East (Lev-Yadun *et al.* 2000). The center of its domestication is widely accepted to be somewhere in the Middle East (Nadia 2010). About 10,000 years ago, as a part of the 'Neolethic Revulation' the first cultivation of wheat occurred which saw a transition from hunting and gathering of food to settled agriculture. These earliest cultivated forms of wheat and their genetic relationships indicate that they originated from south eastern part of Turkey (Shewry 2009; Dubcovsky and Dvorak 2007).

2.2 Cultivation of wheat in Bangladesh

Farmers in Bangladesh grow wheat fitting the crop in their intensive rice-based cropping systems. About 80% of wheat area is planted in a three-crop rotation that is 60% *aus* rice, transplanted *aman* rice-wheat and 20% being jute-transplanted *aman* rice-wheat. About 2 million farmers have benefited from wheat cultivation; about 0.6 million people are employed for a period of 120 man-days during the wheat season, and 20 million m tons of wheat worth US$ 3.4 billion has been produced in a period of 20 years (1975-76 to 1995-96). The production yield of wheat in Bangladesh is relatively declining compared to India and Pakistan (IGC, 2009).

2.3 Production of wheat

Wheat is the most world's widely cultivated crop. At the beginning of the 1960s the total production of wheat was 278 million metric tons and current production is 699.4 metric tons in the world (FAO Food Outlook November, 2012). Total cereal production is 2348.0 million metric tons and wheat covers 29.8% of total cereal production. Wheat production is highest in Asia 45%, Europe 31%, America17%, Africa 3%, Oceania 3% (wheat initiative). In the Asian Far East sub- region, record 2012 crops were gathered in the key producers, namely China and India. The leading wheat production of different countries are European Union 137.5 million tons (MT), China 117.4 MT, India 86.9 MT, United states 54.4 MT, Russian Federation 56.2 MT, Australia 29.5 MT, Canada 25.3 MT, Pakistan 24.3 MT, Turkey 21.8 MT, Ukraine 22.3 MT, Kazakhstan 22.7 MT, Iran 13.5 MT, Argentina 13.7 MT, Egypt 8.4 MT, Uzbekistan 6.3 MT and other countries 59.2 MT (FAO Food Outlook November, 2012). Total utilization of wheat is 697.6 million tons in the world. Wheat is used 473.8 million tons as food, 146.3 million tons as feed, other uses 77.6 million tons and ending stocks 89.2 million tons in 2011-2012. Wheat requirement in Bangladesh is 3.0-3.5 million tons in 2005 and its consumption is increasing 3% per year (Sufian 2005). The area of wheat is 3, 58,022 hectares and production is 99 million tons in 2011-2012 in Bangladesh (BBS estimation of wheat, 2011-2012). To fulfill this requirement export is must. The leading exporters are Argentina, Australia, Canada, EU, Kazakhstan, and Russian Fed., Ukraine and the United States in the world.

2.4 Effect of variety on growth, yield and yield attributes of wheat

Tariq (2010) carried out an experiment at Research Area, College of Agriculture, Dera Ghazi Khan. Two wheat genotypes V_1: Mairaj-2008 and V_2: Fareed-2006 were used to evaluate the effect of drought introduced at different crop growth stages according to the given irrigation schedules i.e. (i): Control (no drought), ii: Irrigation skip at tillering (20-40 DAS), iii: Irrigation skip at jointing (40 -75 DAS), iv: Irrigation skip at spike emergence (75-90 DAS) and v: Irrigation skip at grain formation (105- 115 DAS). Both of the wheat varieties have no genetic potential to withstand against drought. However, skipping irrigation at grain formation crop growth stage abruptly reduced the grain yield followed by skipping irrigation at tillering stage as compared to rest of the crop growth stages.

Mehmet and Telat (2006) experimented with the trials conducted in two locations and over two years, the adaptation and stability statistics of 20 bread wheat genotypes were estimated for yield performances. There were differences in stability performances among the genotypes for the traits of plant height, grain numbers spike^{-1}, grain weight spike^{-1}, 1000 kernels weight and grain yield.

Jalleta (2004) conducted an experiment in farmers' level with a number of improved bread wheat varieties for production in the different climatic zones. Farmers identified earliness, yield and quality as the main criteria for adaptation of wheat varieties and they also found that the variety HAR-710 gave 2.56 t ha^{-1} and PAVON-76 gave 2.49 t ha^{-1}.

Sulewska (2004) carried out an experiment with 22 wheat genotypes for comparing vegetation period, plant height, number of stems and spikes, yield per spike and plant, resistance to powdery mildew and brown rust. He found a greater variability of plant and spike productively and of other morphological characters and he also reported that the variety Waggershauser Hohenh Weisser Kolben gave the highest economic value among the tested genotypes.

Thousand grain weight of any crop depends on its size. Usually grain weight increases with the increase of grain size. A good number of literatures are available on the variability of this trait.

Sood *et al.* (2010) found that 1000 grain weight and grain color in raw, sprouted and puffed wheat was 37.4, 37.6 and 37.2 g, respectively

2.5 Effect of sowing date on growth, yield and yield attributes of wheat

The major non-monitory inputs for enhancing wheat production is optimum time of sowing which is the most important agronomic factor affecting the growth and development of plants. Some of the pertinent literatures regarding effect of sowing time in different location of the world have been presented below-

Junjie *et al.* (2007) conducted an experiment in Xinjiang, China and found the effects of sowing date (5, 10 or 15 October) and sowing rate on the yield and quality of winter wheat (cv. Xindong 24). The yield, number of ears, 1000-kernel weight, and number of kernels per ear decreased, whereas protein content, wet gluten content, and dough development increased as sowing was delayed.

Shah *et al.* (2006) conducted a field experiment to study the effects of sowing dates (1 November, 16 November, 1 December and 16 December 1999, and 1 January and 1st January 2000) on the performance of wheat cultivars (Tatara-96, Inqilab-91, Bakhtawar 92 and Dera-98) in Peshawar, Pakistan. Among the cultivars, Tatara-96 was superior in terms of seedling emergence (131.06 seedlings m^{-2}), number of productive tillers (227.72l m^2), spike length (9.83 cm) grain yield (2666.70 kg ha^{-1}), biological yield (7943.0 kg ha^{-1}) and harvest index (36.44%). Tatara-96 showed optimum productivity when sown on the lst or 3rd week November.

In a similar experiment conducted by Hossain *et al.* (2011) in Bangladesh, using eight dates of sowing (November 8, November 15, November 22, November 29, December 6, December 13, December 20 and December 27) and eight wheat varieties and concluded that highest days to physiological maturity and harvest maturity were recorded under November 8 sowing crop which were significantly higher than late sown conditions.

Ahmad *et al.* (2005) conducted a field experiment in Pakistan during 2004 to study the effects of sowing rate (100, 125 and 150 kg ha^{-1}) and date (3 and 18 November, and 3 December), and chemical weed control on the yield of wheat. The values for the number of tillers, plant height, 100-grain weight and crop yield were the highest with sowing on 3 November and were higher with weed control applications. Crop yield decreased with the increasing sowing rates.

Singh and Singh (2005) conducted a field experiment to assess the effects of different sowing dates (15 and 30 November and 15 and 30 December) and inoculum levels (0, 1 and 2 larvae g^{-1} of soil) on the pathogenic potential of two populations (Sirsa and Mahendergarh) of

Heterodera avenae on wheat (*Triticum aestivum*) cv. WH-147 in Haryana, India. Wheat sowing on 15 November proved to be the most effective recording the highest yield. The number of grains per ear head was highest in the 15 November sown wheat treated with 0 larvae g^{-1} of soil, in both populations.

Hossain *et al*. (2015) conducted an experiment at Bangladesh with three wheat varieties (BAW 1051, BARI Gom 27 and BARI Gom 28) with normal (November 25) and late sown (December 10, December 25 and January 10) conditions and concluded that in late sowing conditions, the grain yield was reduced by 4.5-17.8% in BARI Gom 28, 0.4-30.9 % in BARI Gom 27 and 5.8-20.4% in BAW 1051. It was also observed that grain yield was found to be reduced by about by 8.6-12.6% in BARI Gom 28, 12.8-13.5% in BARI Gom 27and 13.6-15.8% in BAW 1051 from irrigated timely sowing condition for each 1°C rise in average mean air temperature during booting to maturity.

Lathawal *et al.* (2005) conducted a field experiment during the rabi season of 2002-03 in Kurukshetra, Haryana, India to determine the effect of sowing under zero tillage conditions on wheat (cv. WH-711) productivity. Treatments comprised: 1 November, 7 November, 14 November, 21 November, 28 November, 4 December, 11 December, and 18 December. Delayed sowing of wheat from 7 November to 14 November, 21 November, 28 November, 4 December, 11 December and 18 December showed grain yield reductions by 11, 13, 42, 54, 57 and 61 kg per day per hectare, respectively.

In a similar experiment conducted by Hossain *et al*. (2011) in Bangladesh, using eight dates of sowing (November 8, November 15, November 22, November 29, December 6, December, December 20 and December 27) with eight wheat varieties (Sourav, Gourab, Shatabdi, Sufi, Bijoy, Prodip, BARI Gom 25 and BARI Gom 26) and concluded that the highest 1000-grain weight was recorded by Prodip variety sown under November 29, the highest grain yield was recorded by Shatabdi variety under November 29 and December 6 sown conditions whereas Bijoy and Prodip varieties showed highest grain yield under December 13 sowing.

Kumbhar *et al.* (2004) conducted a field experiment on sandy loam soil at Pirsabak (Pakistan) to determine the economics of wheat production using different sowing dates, sowing rates and weed control methods. The treatments comprised three planting dates (October 15, November 15 and December 15), three seeding rates (50, 100 and 150 kg per hectare), and three weed control methods (no weeding, hand weeding and chemical weeding). Comparing the net benefits and marginal rates of return, results revealed that mid planting (15th November) with 100 kg per hectare seeding rate and with chemical weeding is beneficial than early (15th October) and late (15th December) sown crop; it gives the highest marginal rate of return (766%) compared to the other treatments.

Mohaghegh (2003) conducted a field experiment in Neyriz region, Iran. Wheat cultivars Roushan, Falat and Ghods were sown on 6 and 21 November, and 7 December. The interaction effects between sowing date and cultivar were significant. Sowing in 21 November resulted in the highest yield (7616 kg ha^{-1}). Cultivar Falat recorded the highest mean yield (7000 kg/ha). Spike density, spikelets per spike, number of seeds and seed weight were lowest with sowing on 22 December.

Al-Khawlani (2003) conducted a field experiment in Yemen during the winter of 1989-91 and found the effects of sowing date (1 and 15 December, and 1 and 15 January) on the performance of wheat cultivars Mukhtar, Marb-1, Aziz and Sonalika, as well as on the incidence of yellow rust in the crop caused by *Puccinia striiformis*. Mukhtar recorded the highest yield, followed by Marb-1, Aziz and Sonalika. Delay in sowing prolonged the number of days before flowering, reduced plant height and increased the incidence of yellow rust in the crop. Sowing wheat on 1 or 15 December resulted in the highest 1000-grain weight, whereas sowing on l December resulted in the highest biomass production.

Haider (2002) reported that early sown plants (November 15) had the highest spike length, grains spike^{-1} and 100-grain weight and late sown plants (December 5) resulted the lowest values of these parameters of wheat.

Seyed and Raei (2011) reported 190 days after planting, crop growth rate was zero, and then it had negative trend until 105 days after planting, which became stable. The increase in CGR may be due to accelerating the photosynthesis activity. The decrease in crop growth rate towards maturity is due to senescence of leaves and decrease of leaf area index.

Zafar *et al.* (2010) conducted an experiment with sowing dates and reported that Plant height increased up to November 15 planted wheat, but a decreasing trend was observed in late planted wheat.

A field experiment was conducted by Ahmed *et al.* (2006) at Farming System Research and Development (FSRD) site, Chabbishnagar, Godari, Rajshahi under rain fed condition. They concluded that number of tiller increased significantly with early sowing (30 November) in all varieties in both the years.

2.6 Effects of heat stress on growth and yield of wheat

Wahid *et al. (*2007) reviewed that photosynthesis is the most sensitive physiological process to elevated temperature.

Sial *et al.* (2005) conducted an experiment in Tandojam, Pakistan during 2001-02 and studied the effect of the time of sowing and heat stress on the yield and yield-associated traits of wheat genotypes. Twenty advanced wheat genotypes, including the local control cultivar Sarsabz, were screened fewer than 2 sowing dates, i.e. normal sowing (9 November) and late sowing (12 December). Delayed planting adversely affected the yield and yield components of wheat genotypes. Twelve genotypes produced higher grain yields (more than 4000 kg ha^{-1}) than Sarsabz under normal sowing, while 4 genotypes (V-7005, SI-91195, PR-70 and 97B2210) had higher grain yields than Sarsabz under late sowing.

On the basis of heat susceptibility index values, BARI Gom 26 and Shatabdi were highly tolerant to early heat stress and moderately tolerant to extremely late heat stress while Sufi was highly tolerant to extremely late heat stress and moderately tolerant to early heat stress. All other varieties were susceptible to heat stress, among which Gourab was the most susceptible followed by Sourav, Prodip, BARI Gom 25 and Bijoy varieties of wheat in Dinajpur, Bangladesh (Hossain *et al*. 2013).

Khatun *et al*. (2015**)** conducted an experiment at Bangladesh using three wheat varieties (BARI Gom 25, BARI Gom 26, and Pavon 76) concluded that at high temperature, due to high leaf temperature and low transpiration rate, maximum reduction of seedling growth was recorded in Pavon 76 (17%) as compared to minimum in BARI Gom 26 (5%).

Due to heat stress under late sown conditions (December 27), the highest yield reduction was observed in Sourav (46%) followed by Sufi (43%) and lowest reduction was in Shatabdi (27%) followed by Bijoy (32%) and Prodip (35%). When the phenological, growth and yield attributes took into consideration, Shatabdi performed best under heat stress followed by Bijoy and Prodip, while Sourav and Sufi were sensitive to heat stress in Dinajpur, Bangladesh (Hossain *et al*. 2012).

2.7 Role of Zn and B in production of wheat

The yield of any crop like wheat is very closely related to the supply of plant nutrients. The role of macro and micronutrients are crucial in wheat production in order to achieve higher yields (Arif *et al.* 2006). Among micronutrients, Zinc and Boron are the most important micronutrient elements those play a significant role in crop production. Micronutrients deficiency has become a major constraint for wheat productivity in many countries of the world may be due to their low total contents or decreasing availability of them by soil aggregate fixation (Jafarimoghadam 2008; Ranjbar and Bahmaniar 2007). Micronutrients have prominent affects on dry matter, grain yield and straw yield in wheat (Asad and Rafique 2000).

2.8 Effect of Zn on yield and yield attributing Characters as well as nutritional quality of wheat

Zinc (Zn) is a micronutrient which is required for plant growth and development relatively to a smaller amount. Zinc is involved in a diverse range of enzymatic activities. Zinc is an important essential element present in plant enzymatic systems.

Mekkei and El-Haggan Eman (2014) conducted two field experiments to study the effect of Cu, Fe, Mn, Zn foliar application on yield and quality of four wheat cultivars (Sids 13, Sakha 94, Misr 1 and Gemeiza 7). Results showed that sowing Sids 13 cultivar with foliar application micronutrients (Cu+ Fe+ Mn+ Zn) produce high grain yield and greatest grain protein content.

Bameri *et al. (*2012) conducted an experiment with different microelements (Zn, Fe and Mn) and found that plant height, biological yield ,grain yield and yield components were significantly affected by the application of Zn, Fe, Mn alone and combination. There was a positive effect on yield and yield components of wheat.

Habib (2009) stated that the appearance of micronutrient deficiency in crops reduced quality of grain and production. The treatments were control (no Zn and Fe Application), 150 g Zn ha^{-1} as $ZnSO_4$, 150 g Fe ha^{-1} as Fe_2O_3, and a combination of both Zn and Fe. In this study, parameters such as wheat grain yield, seed-Zn and Fe concentration were evaluated. Results showed that foliar application of Zn and Fe increased seed yield.

Ananda and Patil (2007) reported that a field experiment was conducted on deep vertisol at Research and Development Farm, Karnataka, India. The results of the study indicated that Grain and straw yields were highest (42.23 and 68.79 q ha^{-1}, respectively) with the combined application of Zn at 25 kg ha^{-1} and Fe at 25 kg ha^{-1} and it was least (37.83 and 62.51 q ha^{-1}, respectively) in control (RDF+FYM).

Parihar *et al.* (2005) showed that the application of Zn up to 10 kg ha^{-1} increased the grain yield by 7.2 % over control. In the field experiments on Typical Ustipsamment, the effect of sulphur (0, 25 and 50 kg S ha^{-1}), zinc (0, 5 and 10 kg Zn ha^{-1}) and organic manures (10 t FYM ha^{-1} and 5 t vermi-compost ha^{-1}) were studied on wheat for yield and nutrient uptake by wheat.

2.9 Effect of B on growth, yield and yield attributes as well as nutritional quality of wheat

Boron activates certain dehydrogenase enzymes, facilitates sugar translocation and synthesis of nucleic acids and plant hormones, which is essential for cell division and development. The element has more influence on reproductive development than on vegetative.

Sultana (2010) conducted an experiment at BAU farm, Mymensingh to see the effect of foliar application of B on wheat. Boron application exerted significant influence on the yield and grain set of wheat. In a field experiment at BAU farm, Mymensingh observed that grain yield was significantly influenced by different rates of B.

Boron deficiency is the second most widespread micronutrient problem. Whenever the supply of boron is inadequate, yields will be reduced and the quality of crop products is impaired, but susceptibility varies considerably with crop species and cultivars (Alloway 2008).

Halder *et al*. (2007) conducted a field trial during rabi season in Calcareous Brown Floodplain Soils of Regional Agriculture Research Station (RARS), Jessore in Bangladesh with the objective of evaluating the response of wheat varieties to different levels of B and to determine the optimum dose of B for maximizing yield of wheat cultivars Protiva, Gourab and Sourav. They observed that Protiva along with 2 kg B ha^{-1} produced significantly the highest yield in both the years with the highest mean grain yield (5.3 t ha^{-1}) by 66% increase over B control

2.10 Interaction effect of Zn and B on wheat

Nadim *et al.* (2013**)** conducted an experiment investigate the effect of micronutrients and their application methods on wheat. Main plot possessed five micronutrients viz., Zn, Cu, Fe, Mn and B while application methods (side dressing, foliar application and soil application). The results revealed that different micronutrients significantly interacted with the application methods for physiological and agronomic traits and grain yield. Soil application best interacted with boron for producing higher number of tillers, grains $spike^{-1}$, grain yield and almost all the physiological traits.

Singh *et al.* (2008) conducted an experiment to study the individual and interactive effects of zinc (0, 5 and 10 mg Kg^{-1} soil) and boron (0, 0.75 and 1.5 mg Kg^{-1} soil) on enzymatic activity and nutrient uptake in wheat (var. HD2285). The results show the interaction of zinc and boron was found positive up to the level of B at 0.75 and Zn at 5 Kg^{-1} soil on increasing the leaf B, leaf Zn concentration and activity of carbonic anhydrase and decreasing the activity of starch phosphorylase and peroxidase.

2.11 Nutritional analysis of wheat

The major source of flour for products such as bread, biscuits, chin-chin, meat pie and cake is wheat flour. Wheat is an attractive option as a 'first generation biofuel' as the high content of starch is readily converted into sugars (saccharification) which can then be fermented into ethanol. Recently Murphy and Power (2008) reported that the gross energy recovered in ethanol using wheat was 66 GJ $ha^{-1}a^{-1}$; but that this only corresponds to 50% energy conversion and that the net energy production is as low as 25 $GJha^{-1}a^{-1}$.

Protein

Protein from the structural elements of cell and tissue in the human body and are considered as the basis of life, but they are also essential components in different food system.

Rahman and Kader (2011) tried to find out the comparative nutritive values and physiochemical properties of five new varieties of wheat seeds. They stated that total protein content of wheat varieties ranged from 9.10% to 10.01%.

Branlard *et al.* (2001) studied on 162 bread wheat varieties and observed that grain protein content varied from 8.30 to 17.6% and grain hardness varied from very soft to very hard.

Qazi *et al.* (2003) worked on two varieties of wheat and tried to find out the proximate composition. They found that it contains 9.20 and 10.68 percent protein.

Grain proteins of wheat can also be divided into structural/metabolic (non-gluten) and storage protein (gluten) (Shewry *et al.* 2003).

Rehman *et al.* (2005) observed that whole wheat flour contains10.58 percent crude protein.

Ikhtiar and Alam (2007) observed some selected varieties of wheat from Sindh and Punjab. They found the net protein in the range of 9.15-13.80%.

Gulzar *et al.* (2010) reported that different wheat varieties contained 10.30 to 11.72% crude Protein. Percentage of wet and dry gluten ranged from 24.30 to 30.06% and 8.40 to 10.40%.

The baking quality of wheat flour is mainly dependent on the quantity and quality of the flour proteins (Wujun *et al.* 2007).

Carbohydrate

It is well known that starch¸ total sugar and fibre are the main constituents of carbohydrate. Kaur *et al.* (2000) compared four wheat varieties viz. WH-542, Sonak, WH-533 and UP- 2338 for carbohydrate composition and found that the reducing and non- reducing sugars were in the range of 36 to 46 and 152 to 247mg 100g^{-1} flour.

Madan *et al.* (2003) observed carbohydrates and protein content of developing grain of wheat cultivars and found a progressive decrease of total sugars, reducing sugars and non reducing sugars content in the developing grain.

Kumar *et al.* (2011) reported that wheat contains 1.7% total sugars, 66.8% starch and 68.5% carbohydrates.

Starch

Wheat starch is commonly used to produce modified starch, all of which find uses in food and nonfood applications (Sayaslan 2004 and Sayaslan, Seib, Chung 2006).

Shahedur Rahman and Abdul Kader (2011) analyzed on the comparison of nutritional and physicochemical properties of Bangladeshi wheat verities and observed that starch content of wheat flour was 67.50% to 69.50% and reducing sugar was 5.33 mg g^{-1} to 8.60 mg g^{-1}.

Oluwamukomi *et al.* (2011) experimented on physicochemical and sensory properties of wheat-cassava composite biscuit enriched with soy flour and determined each composition characteristics and found 68.69% starch in whole wheat flour.

Naik *et al.* (2007) compared three types of wheat and found that triticale type wheat had higher total sugars (5.7%), non-reducing sugars (4.5%) and starch content (64.2%) as compared to durum and bread types wheat (5.6, 4.3, 62.9 and 5.6, 4.4, 62.7 percent).

Baljeet *et al.* (2010) studied on functional properties and incorporation of buckwheat flour for biscuit making determined the nutritional value and observed that starch was present 75.74% in flour.

Masood *et al.* (2004) researched on the effect of moisture on the shelf life of wheat flour and notified that starch was remain 70% in wheat flour and suggested that it effects on the color of the flour.

Ash

Ash is the residue that remains after the complete combustion of the organic compounds of a food product. The estimation of the ash content in cereals enables the classification of flours. The ash content is a measure of the total amount of mineral present in wheat flour.

Ahmed *et al.* (2005) reported that reported that the ash content of different varieties of wheat were variable and range from 0.52% to 0.68%.

Khan and Zeb (2007) worked on seven different varieties of wheat and reported that it contains 1.44 to 2.10% ash.

Ndife *et al.* (2011) reported that wheat contained fewer amounts of ash (1.5%).

Mineral

Minerals play an important role in maintaining proper function and good health in the human body (Bhat *et al.* 2010).

Basically two forms of minerals: macro and trace minerals. Macro means "large" which requires in larger quantity for body needs as compared to trace minerals. (Shabbir 2009).

An average adult requires an intake of more than 100 mg per day of macrominerals and trace elements with a recommended daily intake within the microgram range to maintain specific functions in the body (Ho *et al.* 2012).

Mineral plays very vital role for the synthesis of proteins and cell functions, form of hemoglobin in human body (American Rice Institute 2004).

Minerals found in wheat bran (WB) include iron (Fe), zinc (Zn), manganese (Mn), magnesium (Mg) and phosphorus (P). (Aivaz and Mosharraf 2013)

Nabila *et al.* (2012) found that the calcium, iron and zinc contents of wheat were 33.66, 3.21 and 2.1mg $100g^{-1}$, respectively.

Most of the seed-Zn is present in the embryo and aleurone layer, whereas the endosperm is very low in Zn concentration. Zn concentrations were found to be around 150 $mg.kg^{-1}$ in the embryo and aleurone layer and only 15 mg kg^{-1} in the endosperm. (Ozturk *et al*. 2006)

From the above review discussion we can conclude that sowing date and micronutrient (B and Zn) have marked effects on growth, yield contributing characters and yield of wheat. Most of the authors are of the opinion that grain set failure due to micronutrient deficiency and high temperature during flowering stage that arises from late sowing (December) could be again causes of yield loss of wheat in Bangladesh . Some studies revealed that zinc and boron above certain levels increased the yield and yield parameters and quality of wheat. Therefore, the present investigation is well justified to find out the optimum sowing time and doses of micronutrient (B and Zn) fertilizer for wheat cultivation under a typical agro- climatic situation of Rajshahi (AEZ-11).

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3
MATERIALS AND METHODS

The experimental field is located at the Regional Station, BWMRI, Rajshahi during the period from 2015 to 2016 and 2017 to 2018 to study the Response of micronutrients on Growth and yield of wheat under late seeding heat stress condition. The details of the methods followed and materials used in the study are described below-

3.1 Description of the Experimental Site

3.1.1 Location

The experimental field is located at Bangladesh Wheat and Maize Research Institute (BWMRI), Regional Station, Rajshahi is a newly established research institute that was previously known as Wheat Research Centre (WRC). Geographically the experimental field was located at the Agro-Ecological Zone 11 (AEZ-11) (BBS, 2013). The location of the experimental site has been shown in Plate 1.

3.1.2 Soil

The experiment was carried out in a typical wheat growing soil of the Regional Station, BWMRI, Rajshahi, during robi season of 2015. The farm belongs to the general soil type, "calcareous dark gray soil" under High Ganges River floodplain (AEZ-11) (FAO, 1988). The top soil is silty loam and slightly alkaline in reaction. Experimental plot was also high land, having p^H 8.2. The physicochemical property and nutrient status of soil of the experimental plots are given in Appendix I, IIA and IIB.

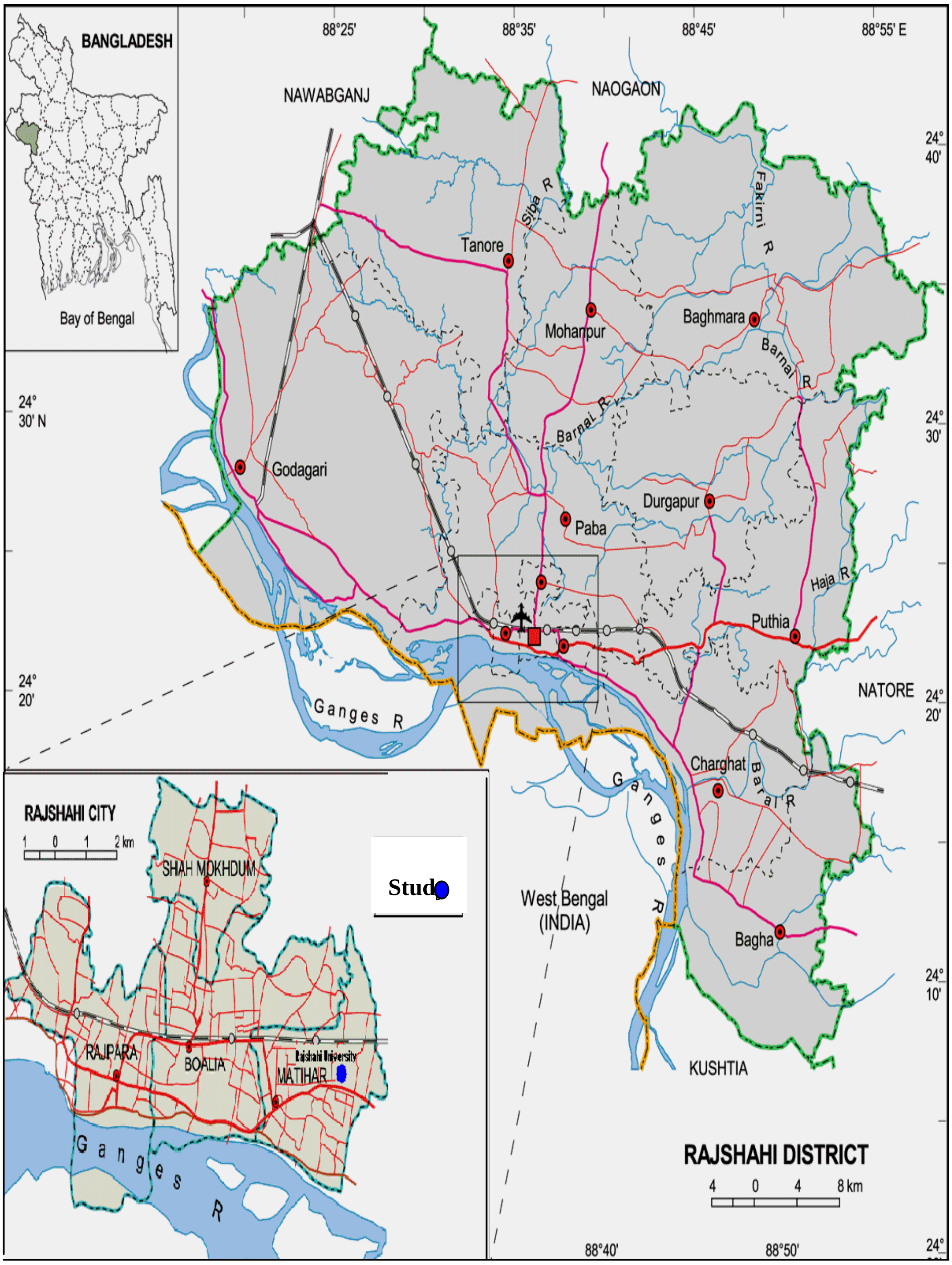


Plate 1. Location map of the study area

3.1.3 Climate

The climate of Regional Station, BWMRI, Rajshahi, Bangladesh is tropical monsoon characterized by distinct season. The winter is a dry and cool season and receives about 2% of the total rainfall mostly as occasional drizzles between November and February. The premonsoon hot season prevails from March to April having the highest temperature (42^0C). The mean monthly temperature ranges from 10°C in January to 30°C in April, July and August, the annual temperature is about 27°C. The maximum (42°C) and minimum (8°C) temperatures have been recorded in the months of May and February, respectively. The mean rainfall variation 1500-2200 mm. Meteorological data were collected from the Regional Meteorological Station, Shyampur, Rajshahi. The monthly maximum, minimum and mean temperature, rainfall and relative humidity at the experimental site during the period of study (From November, 2015 to April, 2016 and November, 2017 to April 2018) have been presented in Appendix III.

3.2 Experimental Treatments

The treatments included in the experiment were as follows:

Factor A: late seeding heat stress condition

I. 25^{th} November (D_1)
II. 10^{th} December (D_2)
III. 25^{th} December (D_3)

Factor B: Varieties

I. BARI Gom 26 (V_1)
II. BARI Gom 28 (V_2)

Factor C. Micro-nutrients

I. Control (M_0)
II. Boron (1.25 kg ha^{-1}) (M_1)
III. Zinc (5.30 kg ha^{-1}) (M_2)
IV. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3)

3.2.1 Planting material

Two wheat varieties namely BARI Gom 26 and BARI Gom 28 were selected for the study and were collected from Regional Station, BWMRI, Rajshahi.

3.3 Experimental Set up

Different wheat varieties were the test variety of the experiment. All the varieties were developed by the Wheat Research Centre under Bangladesh Agricultural Research institute (BARI), Gazipur.

3.3.1 Experimental design and Layout

The experiment was conducted in a Split-split plot design with 3 replications (Figure 1). The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into 3 main plots in where different sowing date was assigned. Each main plot was further divided into 2 unit plots or sub-plots in which different varieties were applied and each sub plot was divided into 4 sub sub plots where different micronutrient levels were randomly distributed. There were altogether 72 (3x3x2x4) unit plots, each plot measuring 1 m x 4 m. Inter-block and inter-plot spacing were 1m and 0.5 m, respectively. Number of lines in each plot was 5 and line to line distance was 20 cm.

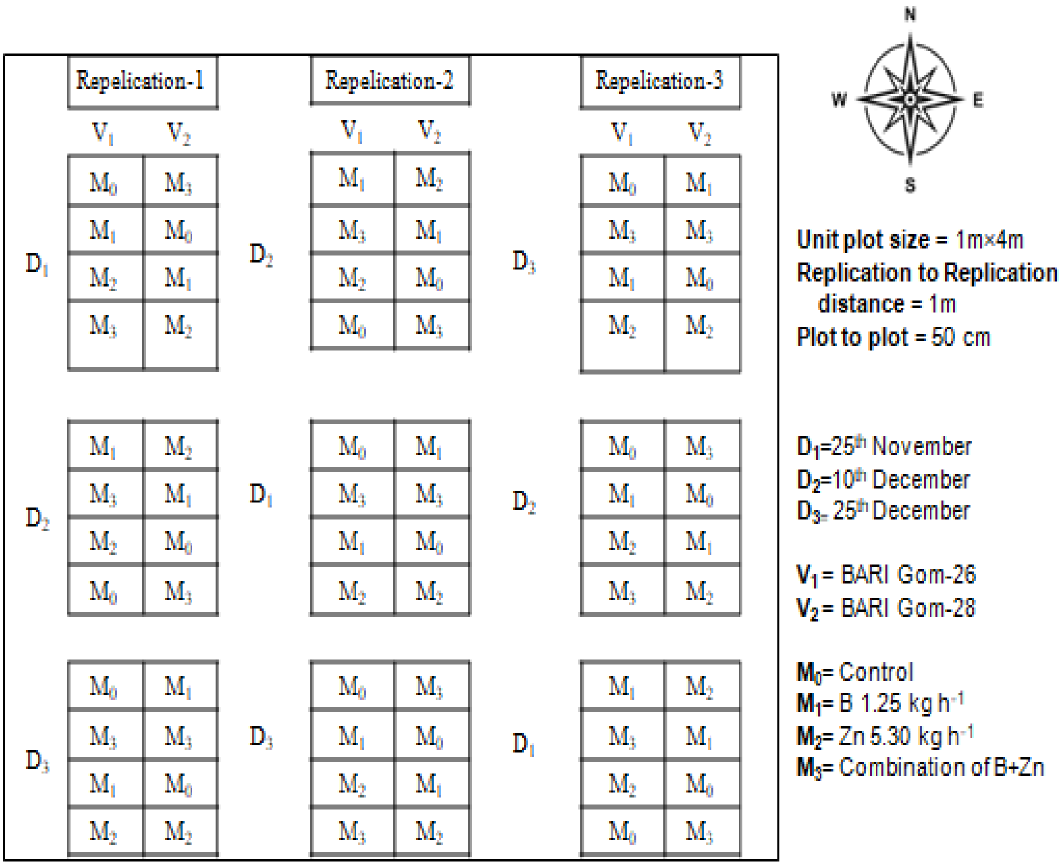


Figure 1: Layout of the experimental field

3.3.2 Description of wheat varieties under study

i. BARI Gom 26

BARI developed this variety and released in 2010. This variety developed by crossing between with three alien wheat variety and select as BAW 1064 from different generation and named as BARI Gom 26. The grain yield ranges from 3500-4500 kg ha^{-1} under optimum management. The variety is highly tolerant to terminal heat stress. This variety is relatively shorter in height about 92-96 cm. The number of tillers plant^{-1} is 5-6 and the leaves are wide, broad, recorded and deep green in color. It requires 60-65 days to heading and 104-110 days to mature. Spike is medium with 45-50 grains per spike. Grains are amber in color, glossy and larger in size (1000-grain weight 48-52g). Seeds contain 60 - 65% carbohydrate (Plate 2.).

ii. BARI Gom 28

The variety developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and released in 2012. The origin of this variety is CIMMYT Mexico. The main characteristics of this variety is short duration crop (it takes 102-108 days to maturity), the plant height is about 95-100 cm. It gives 4000-5500 kg ha^{-1} grain yield and also heat tolerant variety. This variety gives 15-20% higher yield than Shatabdi. The number of tiller $plant^{-1}$ is 4-5. It has required 55-60 days for spike initiation. Spike is broad with 45-50 grain $spike^{-1}$. Grains are bright and medium in size (1000 grain weight 43-48 g). Tillers become straight in seedlings and plants are deep green in color (Plate 2.).

	
A. BARI Gom-26	B. BARI Gom-28

Plate 2. Variations in seed coat color, seed size and shape of BARI Gom-26 and BARI Gom 28 (A-B)

3.4 Growing of crop

3.4.1 Land Preparation

The first ploughing and the final land preparation were done on 18 October and 22 October in both the year respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before seed sowing and the basal dose of fertilizers was incorporated thoroughly before seed sowing.

3.4.2 Collection of soil sample and analysis

Soil samples were collected before the ploughing of experimental field. Soil samples from 0-15 cm depths were collected from five locations of experimental land. These samples were then composite to make a bulk sample. Then the bulk sample was sieved to remove unwanted materials. This sample was air dried and then preserved in polythene bags for future laboratory analysis from Soil Resource Development Institute (SRDI), Rajshahi Laboratory, Rajshahi. The chemical properties of soil have been presented in Appendix IIA and IIB.

3.4.3 Fertilizer Application

Fertilizer was applied based on BARC fertilizer recommendation guide. Urea, triple super phosphate (TSP) and muriate of potash (MoP) were used as source of nitrogen, phosphorus and potassium, respectively. Triple super phosphate (TSP), urea, muriate of potash (MoP) were applied to the plots at the rate of 110, 220, 95 kg ha^{-1}. Urea was applied in 2 split, first of all two third of total urea and all other fertilizers were applied at the time final land preparation and rest one-third urea was applied at first irrigation. B (Boron) and Zn (Zinc) were applied as 7.41 kg ha^{-1} Boric acid and 14.82 kg ha^{-1} Zinc sulphate as per treatment specification.

3.4.4 Sowing of seeds in the field

Seeds were sown in three dates at 15 days interval (25 November, 10 December and 25 December), opened by specially made a hand plough. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm from the soil surface. Seeds were sown continuously in line on 1st sowing, 25 November 2015 @ 140 kg ha^{-1} and 20 cm apart lines covered by soil manually. Two guards were appointed from early morning to evening to protect the wheat seeds from birds. Two others sowings were done on 10 December and 25 December respectively at the same way of 1st sowing.

3.5 Intercultural operations

Various intercultural operations were accomplished for better growth and development of the wheat plants. The following intercultural operations were followed:

3.5.1 Irrigation

Irrigation was done first at 22 days after sowing (Crown root initiation stage) and second at 55 days after sowing (Booting stage) in a controlled way. Excess water of the field was drained out.

3.5.2 Weeding

The crop was infested with some local weeds such as Bathua (*Chenopodium album*), Mutha (*Cyperus rotundus*) and durba (*Cynodon dactylon*) etc. Weeding was done by the help of niri when necessary. Herbicide roundup 75ml $10L^{-1}$ per 5 decimal was sprayed at the time of land preparation. Afinity 2.5g L^{-1} per 5 decimal was sprayed only for selective broad leaf weed, two weeding were done, one at 35 DAS and other at 65 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.5.3 Seed Treatment

Before sowing collected seeds were treated with Provax 200-Ec @ 2.5 g powder for kg^{-1} seed to prevent seeds from the attack of soil borne diseases.

3.5.4 Protection against insect and pest

The crop was attacked by different kinds of insects (cereal aphid and grass hopper) during the growing period. The experimental plots were sprayed at 35 days with appropriate insecticides to control the insects. Insecticide was applied to the plots after irrigation at afternoon. At early stage of growth, few worms (*Agrotis ipsilon*) and virus vectors (Jassid) attacked the young plants. To control these pests, Dimacron 50 EC was sprayed at the rate of 1litre per ha.

3.6 Harvesting, post harvest operations and sampling

The crop was harvested at different dates on the basis of sowing time. Samples were collected from different places of each plot leaving undisturbed two-meter square in the centre. The crop was cut at the ground level. The selected sample plants were then harvested, bundled, tagged and carefully carried to the threshing floor in both the years in order to collect the data.

3.7 Plant sample collection

From each plot five rows of crop were used for collecting data on growth and phenological parameters. Growth study was started from crown root initiation stage (CRI) and continued up to physiological maturity stage. Five plants per plot were carefully uprooted randomly at each time. Each plant sample was separated into leaf, stem and spike (when appeared). Number of tillers plant^{-1} was then counted.

3.8 Data collection and recording

Data on plant characteristics were collected two times such as before harvest and after harvest. The plants in the outer rows and the extreme end and middle rows were excluded to avoid the border effect.

3.8.1 Recording of data before harvest: Recording of data was collected before harvest at CRI, tillering, booting, heading and anthesis and physiological maturity stages.

i. Total Dry Matter (TDM)
ii. Leaf Area Index (LAI)
iii. Crop Growth Rate (CGR)
iv. Relative Growth Rate (RGR)
v. Net-Assimilation Rate (NAR)
vi. Leaf Area Ratio (LAR)

3.8.2 Recording of data after harvest: Recording of data was collected after harvest**.**

i. Plant height at harvest (cm)
ii. Number of total tillers plant^{-1}
iii. Number of effective tillers plant^{-1}
iv. Number of spikelets spike^{-1}
v. Number of grains spike^{-1}
vi. Spike length (cm)
vii. 1000-grain weight (g)
viii. Grain yield (t ha^{-1})
ix. Biological yield(t ha^{-1})

3.8.3 Biochemical Analysis of wheat grain:

i. Total Soluble Protein
ii. Total Soluble Carbohydrate
iii. Starch
iv. pH Test
v. Ash content
vi. Total Soluble Solid
vii. Iron Status
viii. Calcium Status
ix. Phosphorus Status
x. Zinc Status

3.8.4 Growth analysis technique

To determine different growth attributes the harvest interval method (classical technique) was followed (Radford 1967). W_2 and W_1 are the total dry weights; LA_2 and LA_1me the total leaf area per plant at t_2 and t_1; the latter and the former harvest respectively. A brief outline of the data recording procedure has been given below:

i. Total dry matter (TDM)

Total dry matter refers to the oven dry weight of total parts of a plant.

$\therefore$ TDM= Stem weight + leaf weight + spike weight (when appeared).

Five plants plot^{-1} were randomly taken from specific side of the plot for measuring the total dry matter. In the next, the leaf, stem and spike (when appeared) were packed separately in labeled brown paper and dried under sunshine for three to four days or were oven dried for 72 hrs at 70-80^{0}C. After oven drying, the samples were weighted separately by using an electric balance, which gave leaf dry weight, stem dry weight as well as spike dry weight. Then total dry matter (TDM) was computed according to rules as mentioned earlier and finally it was expressed in g m^{-2}.

ii. Leaf area index (LAI)

Leaf area index (LAI), the ratio of total surface area of the leaves to total land area, provides the photosynthetic surface area of the species. The leaf area index was calculated by using the following formula:

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

$$= \frac{LA}{P}$$

Where, LA = Leaf area (cm^2)

P = Ground area (cm^2)

The measurement of leaf area was started from CRI and continued up to physiological maturity stages. The leaf area of the collected leaves was measured by disc method. For leaf area determination, five leaf segments of eight cm lengths were taken and weighed after oven-drying and the leaf area was estimated manually in the following way:

$$\text{Leaf area (LA)} = \frac{\text{Area of segments} \times \text{Weight of leaves}}{\text{Weight of segments}}$$

iii. Crop growth rate (CGR)

The dry matter accumulation of the crop per unit land area in unit of time is referred to as growth rate (CGR). Crop growth rate refers to increase of plant materials per unit of time. It is expressed as g of dry matter produced per day.

The mean CGR value for the crop during the sampling intervals has been computed by using the formula:

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \quad \text{gm}^{-2}\ \text{day}^{-1}$$

Where,

W_1= Total dry weight at time, t_1

W_2= Total dry weight at time, t_2

iv. Relative growth rate (RGR)

The relative growth rate at which a plant incorporates new material into its sink is measured by "Relative Growth Rate" of dry matter accumulation and is expressed in g $g^{-1}day^{-1}$. Relative Growth Rate was worked out by the following formula:

$$\text{RGR} = \frac{(\log_e W_2 - \log eW_1)}{(t_2 - t_1)}$$

v. Net assimilation rate (NAR) = $\frac{(W_2 - W_1)(\log_e LA_2 - \log eLA_1)}{(LA_2 - LA_1)(t_2 - t_1)}$

vi. Leaf area ratio (LAR) = $\frac{(\log_e W_2 - \log eW_1)\ (LA_2 - LA_1)}{(W_2 - W_1)\ (\log_e LA_2 - \log eLA_1)}$

3.8.5 Procedure of data collection at harvest

After sampling the crop from half of each plot was harvested at full maturity to record the data on grain yield and straw yield. The data on yield and yield contributing characters were recorded by using the following procedure.

i. Plant height (cm)

The plant height was taken from three randomly selected plants of each plot. The height of the plant was measured from the base of the plant to the tip of the uppermost spikelets of the spike with the help of meter scale.

ii. Number of total tillers plant^{-1}

Tillers which had at least one leaf visible were counted. It included both effective and non-effective tillers.

iii. Number of effective tillers plant^{-1}

The spike, which had seeded was regarded as effective tillers.

iv. Number of spikelets spike^{-1}

Spikelets spike^{-1} was recorded and mean was calculated later on.

v. Number of grains spike^{-1}

Presence of any food material in the spikelet was considered as grain and total number of grains present on each spike was counted. Later on, mean was calculated.

vi. Spike length (cm)

Spike length was measured from the neck node of the rachis to the apex of last grains of each spike without awn length.

vii. 1000-grain weight (g)

One thousand grains were counted from grains of harvesting crops grown one square meter area at the center of each treatment plot, dried properly and weighed by using an electric balance.

viii. Grain yield (t ha^{-1})

Grain yields were determined by harvesting crops grown one square meter area of each plot. The harvested samples were then threshed, dried and weighed by using balance and finally the values were expressed in t ha^{-1}.

ix. Biological yield (t ha^{-1})

Grain yield and straw yield altogether regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield

3.8.6 Physicochemical analysis technique of wheat grain

Some constituents are determined fairly easily and rapidly, while others require much more time and analytical ability. Consequently, most laboratories are faced with a choice between making a few rather simple determinations of a large number of samples or complete analysis of a limited number of samples. Before undertaking an analysis, the results of which will represent the composition of a crop or a consignment of a food grain, it is necessary to ensure that the sample taken is randomly selected so as to be truly representative of the original bulk and is sufficient in amount.

Methods

Different methods used for quantitative determination of different nutritional quality of the whole wheat grain of two varieties are mentioned here under separate heads.

Sample collection

The samples were collected after harvesting matured wheat during April to determine the nutrient contents of wheat grain.

i. Determination of P^H Content: The P^H of wheat grain was determined by the conventional procedure using a P^H meter.

Equipments: i) Electric balance, ii) Mortar and pestle and iii) Centrifuge machine

Extraction of wheat grain:

About 10g of wheat grain and 100 ml of distilled water were taken in a mortar. The wheat grain were crushed thoroughly in the mortar with a pestle and then filtered through double layer of muslin cloths. The filtrate was then centrifuged for 10 minutes at 3000 r.p.m. and the clear supernatant was collected for p^H determination.

Standard buffer solution: P^H 4.0 or P^H 7.0 buffer tablet (BDH Chemicals Ltd., Poole, England) was dissolved in distilled water and made up to the mark of 100 ml with distilled water.

Procedure:

The electrode assembly of the P^H meter was dipped into the standard buffer solution of P^H 7.0 taken in a clean and dry beaker .The temperature correction knob was set to 28^0C and the fine adjustment was made by asymmetry potentially knob to P^H 7.0. After washing with distilled water the electrode assembly was then dipped into a solution of standard P^H 4.0 and adjusted to the required p^H by the asymmetry potentially knob .The electrode assembly was raised, washed twice with distilled water, rinsed with grain extract and then dipped into the wheat grain solution for recording the P^H of the extract.

ii. Determination of total soluble solids

The total soluble solids (TSS) content in wheat grain was determined by using Abbe refractometer at room temperature (AOAC, 2000, Ayub *et. al.* 2010). Several drops of wheat grain extract from the extract prepared for p^H estimation were placed on the day light plate (angled prism) of the refractometer and sealed the clear plate on top of it. After looking through the eyepiece while pointing the refractometer at a source of direct light, TSS was determined from the percentage scale (0-90 %) of refractometer. Temperature correction was done using the methods as described by Ranganna (1979).

iii. Determination of total soluble protein content

Soluble protein content in wheat grain was determined following the method of Lowry *et al.* (1951).

Equipments:

i) Whatman No 1 filter paper,
ii) Spectrophotometer,
iii) Microfuge tubes,
iv) Pipette,
v) Mortar and pestle,
vi) Centrifuge machine and
vii) Muslin cloth.

Reagents:

1. 2% Na_2CO_3 solution in 0.1 N NaOH (Approximately 0.4g of NaOH dissolved in 100 ml of distilled water and then 2g of Na_2CO_3 dissolved it)
2. 0.5% $CuSO_4.5H_2O$ in 1% Na-Katartarate (Approximately 1 g of Na-Katartarate dissolved in 100 ml of disilled water and then 0.5 g copper sulphate dissolved it).
3. Folin-Ciocalteu’s Reagent-FCR (Diluted with equal volume of distilled water, just before used) and

4. Protein standard (Approximately 10 mg of bovine serum albumin diluted in 100 ml distilled water).

Extraction of wheat grain:

About 5 g of the wheat grain were crushed thoroughly in the mortar with a pestle and homogenized well with 5 ml of distilled water. It was then filtered through double layer of muslin cloth. The filtered was centrifuged at 3000 rpm for 15 minutes and the clear supernatant was transferred in a 50 ml volumetric flask and made up to mark with distilled water. Then 10 ml of diluted solution was taken in another 100 ml volumetric flask and made up to the mark with distilled water (working standard).Water was carefully added avoiding formation of foam.

Procedure:

Reagent 1and 2 were mixed in the ratio of 50:1 and the reagent 3 was diluted just before use. 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1 ml of the standard protein solution were taken and the volume was made up to 1ml with distilled water. 1ml of the sample was taken in a test tube and a duplicate was made. To each of the test tubes (standard and sample) 5.0 ml of (1:2) mixture was added and after 10 minutes 0.5 ml of FCR solution was added. Absorbance of the solution was recorded after 30 minutes at 650 nm. A graph was drawn with the data obtained from the standards and the amount of soluble protein in the sample was calculated from the graph.

Calculation:

Percentage of soluble protein content (g 100 g^{-1} of wheat grain)

$$= \frac{\text{Amount of soluble protein obtained}}{\text{Weight of wheat grain}} \times 100$$

iv. Determination of total soluble carbohydrate content:

Total soluble carbohydrates were estimated by phenol sulfuric acid method (Dubois *et al.* 1956).

Equipments:

i) Whatman No 2 filter paper,
ii) Spectrophotometer,
iii) Microfuge tubes,
iv) Pipette,
v) Mortar and pestle,
vi) Centrifuge machine and
vii) Muslin cloth.

Reagent:

1. 80% ethanol
2. P. phenol (80% phenol)
3. Sulfuric acid.

Extraction of wheat grain:

1g of wheat grain weighted and digested by hot ethanol 80% two times. Each time by 5ml ethanol and then filtered by whatman No.2 filter paper. The extract again mixed with 5ml ethanol and again filtered. Then the extracts diluted by distilled water to the volume of 50ml.

Procedure:

1ml prepared sample placed in a test tube and then 1ml p phenol solution added. The procedure was followed by adding 5ml of sulfuric acid and well shaken.

The yellow-orange color was pipette off and wave length was read in 490 nm by spectrophotometer (Plate 3.).

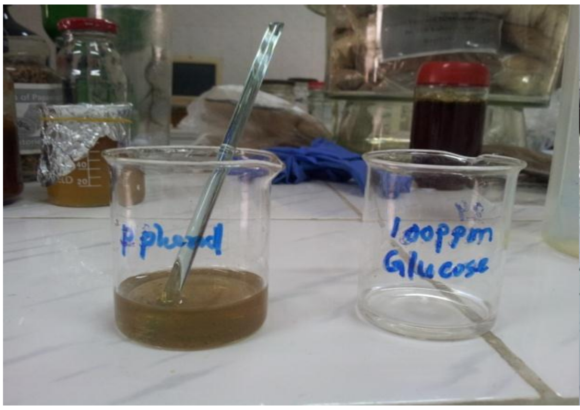
The standard curve was prepared by taking 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of standard glucose solution in different test tube and made the volume up to 1.0 ml with distilled water. 1ml p phenol and 5ml sulfuric acid was added to each test tube and mixed well. All the solution treated similarly as described above. The absorbance was measured at 490 nm.

A reagent blank was prepared by taking 1ml of water, 1ml p phenol and 5ml of sulfuric acid in a test tube and treated similarly.

Calculation: The amount of carbohydrates was calculated from the standard curve of glucose. Finally, the percentage of total soluble carbohydrate present in the wheat grain was determined using the formula given below.

Percentage of total soluble carbohydrate content (g 100 g^{-1} of wheat grain).

$$= \frac{\text{Weight of total soluble carbohydrate obtained}}{\text{Weight of wheat grain}} \times 100$$



A: P. phenol and standard glucose solution

B: Sulfuric acid and phenol


C: Yellow-orange color was pipette off D: Prepared sample

Plate 3. Total soluble carbohydrates were estimated by phenol sulphuric acid method (A-D)

v. Determination of starch content:

The starch content of the wheat grain was determined by the Anthrone method as described in laboratory Manual in Biochemistry (Jayaraman 1981 and Loomis 1937).

Equipments:

i) Mortar and Pestle,
ii) Double layer of muslin cloth
iii) Centrifuge machine,
iv) Water bath,
v) Volumetric flasks,
vi) Test tube,
vii) Glass marbles,
viii) Spectrophotometer.
ix) Beaker and
x) Pipette

Reagent:

1. Anthrone reagent: The anthrone reagent was prepared by dissolving 200mg of anthrone in 100ml of concentrated sulfuric acid. Standard

glucose solution: A standard glucose solution was prepared by dissolving glucose in distilled water. 10 mg of glucose was taken in 100ml volumetric flask and distilled water was added up to the mark.

2. 1M HCl
3. Ethanol

Extraction of wheat grain: About five g of wheat grain powder were homogenized well with 20 ml of distilled water. The content was filtered through double layer of muslin cloth. To the filtrate, twice the volume of ethanol was added to precipitate the polysaccharide, mainly starch. After kept it overnight in cold, the precipitate was collected by centrifugation at 3000 rpm for 15 minutes (Plate 4.). The precipitate was dried over a steam bath. 40 ml of 1 M hydrochloric acid was added to the dried precipitate and heated to about 70ºC. It was then transferred to a volumetric flask and diluted to 100 ml with 1M HCl. 1 ml of diluted solution was taken in another 100 ml volumetric flask and made upto the mark (100 ml) with 1M HCl (working standard).

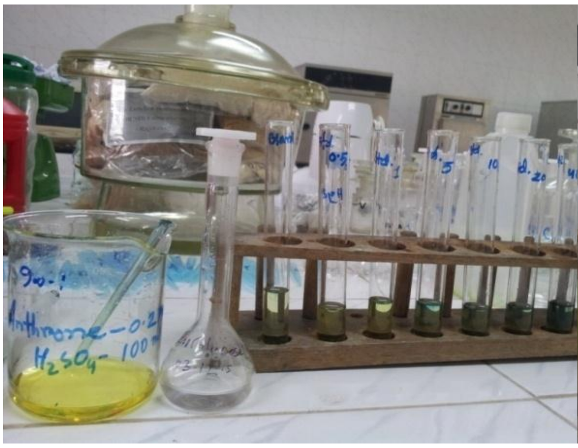
Procedure: Aliquots of 1 ml of the wheat grain from each cultivar was pipette into different test tubes and 4ml of anthrone reagent was added to esch of this solution and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The test tube were placed in a boiling water bath for 10 minutes, then removed and cooled. A reagent blank was prepared by taking 1 ml of 1M HCl and 4 ml of anthrone reagent in a test tube and treated similarly. The absorbance of the blue-green solution was measured at 680 nm in a spectrophotometer.

A standard curve of glucose was prepared by taking 0.0, 0.05, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of standard glucose solution in different test tubes and made up to the volume 1 ml with 1M HCl which contained 0.0, 10, 20, 40, 60, 80 and 100 μg of starch respectively. Then 4 ml of anthrone reagent was added to each test tube and mixed well. All the solutions were treated similarly as described for the sample. The absorbance was measured at 680 nm using the blank containing 1 ml of 1M HCl and 4 ml of anthrone reagent.

Calculation: The amount of starch present in the wheat grain was calculated from the curve of glucose. Finally, the percentage of starch present in the wheat grain was determined using the formula given below:

Percentage of starch content (g 100 g^{-1} of wheat grain)

$$= \frac{\text{Weight of the ash obtained}}{\text{Weight of the sample (Wheat grain)}} \times 100$$



A: Anthrone reagent, standard glucose and blue-green sample solution

B: Extraction of wheat grain

C: Precipitate collected by centrifugation

D: Test tube were placed in a boiling water bath

Plate 4. The starch content was determined by the anthrone method (A-D)

vi. Determination of ash contents:

Ash content was determined by following the method of AOAC, (1980).

Materials:

i) Porcelain crucible.
ii) Electrical balance.
iii) Muffle furnace.
iv) Desiccators.

Procedure:

About 10g of wheat grain were weighed in a porcelain crucible which previously cleaned and heated to about 100 ^{0}C, cooled and weighed. The crucible was placed in a muffle furnace for about six hours at 600 ^{0}C. It was then cooled in desiccators and weighed. To ensure completion of ash the crucible was again heated in the muffle furnace for half an hour, cooled and weighed again. This was repeated till two consecutive weights were the same and the ash was almost white in color (Plate 5.).

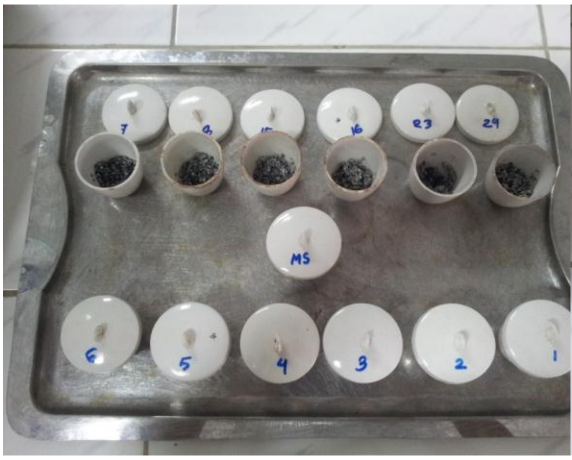
Calculation:

Percent of ash content (g 100 g^{-1} of wheat grain)

$$\frac{\text{Weight of the ash obtained}}{\text{Weight of the sample (Wheat grain)}} \times 100$$

A: Wheat grain were weighed

B: Crucible was placed in a muffle furnace



C: Ensuring completion of ash

D: The ash was almost white in color

Plate 5. Ash content was determined by following the method of AOAC (1980) (A-D)

Determination of Mineral

Stock solution preparation for mineral estimation: The stock solution of wheat grain for mineral estimation was prepared from dry matter. The dry matter of wheat grain was grinded into flour from the mortar and pestle. Approximately 0.5g of each sample in duplicate was taken into digestion tubes and to each of the tubes 5 ml of nitric acid and 2.5 ml of perchloric acid (followed by 2:1) was added and mixed well. The rest tubes were heated to about 100ºC for 10-12 hours in boiling water bath and cooled. Then 2.5 ml of nitric acid was further added to each of the tubes and heated to about 90ºC for 3-4 hours in boiling water bath till the solution become transparent (water color). The solutions were cooled and filtered through Whatmann No.41 filter paper and made up to 100 ml with de-ionized distilled water (working solution). The stock solution was then ready for the estimation of iron, phosphorus, calcium and zinc. All the glassware including digestion tubes were soaked with 30% nitric acid (HNO_3) for 8 hours and finally washed with de-ionizes distilled water.

vii. Determination of Iron content:

Iron content of wheat grain was determined by Colorimetric method (Wong 1928 and Fisk, C.H. and Row, Y.S. 1925).

Equipments: i) Volumetric flask, ii) Pipette, iii) Electric balance and iv) Spectrophotometer.

Reagent:

1. Hydroxylamine solution: 10g of hydroxylamine was dissolved in 100 ml of distilled water and mixed well.
2. Ammonium Acetate Buffer solution: About 250 g of ammonium acetate was dissolved in 150 ml distilled water. Then 700 ml of glacial acid was added.

3. Phenanthroline solution: 100 mg of 1, 10-Phenanthroline monohydrate was taken in a 100 ml volumetric flask and the volume made up to the mark with distilled water by stirring and heating to 80ºC but not to boil.
4. 100ppm Iron standard solution: 100 ppm iron (II) solution was used as standard. The solution contains 100mg of Fe (II) per liter. From this solution 2.5 ml was taken in 50 ml volumetric flask and then made up to the mark with distilled water for preparing 5 ppm stansard Fe (II) solution.

Procedure:

5 ml of the stock solution was pipette into 25 ml volumetric flask. 1ml Hydroxylamine solution and 10 ml Ammonium acetate buffer solution were added and shaken well. The solution was treated with 4 ml of 1, 10-Phenanthroline solution was added and made up to 25 ml with distilled water. The absorbance of the solution was measured at 510 nm in a spectrophotometer.

The standard curve of (Fe^{++}) was prepared by taking 0.0, 0.125, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0 and 5.0 ml of standard Iron solution into 25 ml volumetric flask. Then added 1 ml Hydroxylamine hydrochloride, 10 ml Ammonium acetate buffer and 4 ml of 1,10 Phenanthroline, Then made up to the mark with distilled water and treated similarly.

A reagent blank was prepared by taking 5ml of distilled water and treated as before. The rose to light rose color was pipetted off and the absorbance was measured at 510 nm by spectrophotometer machine.

Calculation: The amount of Iron content in wheat grain was calculated by using the standard curve of iron. Finally, the amount of iron present in the wheat grain was determined using the formula given below:

Amount of Iron (mg 100 g^{-1} of wheat grain)

$$= \frac{\text{Weight of Iron obtained}}{\text{Weight of wheat grain}} \times 100$$

viii. Determination of Phosphorus content:

Phosphorus content of wheat grain was determined following the method as described by Chapman and Parker (1961), Colorimetric method (Fiske C.H. and Row, Y.S. 1925).

Equipments: i) Volumetric flask, ii) Pipette, iii) Electric balance and iv) Spectrophotometer.

Reagent:

1. 5% Ammonium Molybdate solution: 5 g of ammonium molybdate was dissolved in 100 ml of distilled water and mixed well.
2. 0.25% Ammonium Vanadate solution: 0.25 g of ammonium vanadate was dissolved in 100 ml distilled water and mixed well.
3. 5% Sulfuric acid solution: 5% sulfuric acid was prepared from concentrate sulfuric acid with distilled water.
4. Standard Phosphorus solution: 100 ppm phosphorus solution was used as standard. This solution contains 100 mg/liter phosphorus.

Procedure:

5 ml of the stock solution was pipette into a 25 ml volumetric flask. 5ml 5% ammonium molybdate and 5 ml 0.25% ammonium vanadate were mixed well. The solution was treated with 5 ml 5% sulfuric acid and made up to the mark with distilled water. The absorbance of the solution was measured at 420 nm in a spectrophotometer.

The standard curve was prepared by taking 0.0, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 1.0, 1.5 and 2.0 ml of 100 ppm standard phosphorus solution into 25 ml volumetric flask. Then added 5ml 5% ammonium molybdate and 5 ml

0.25% ammonium vanadate .The solution was treated with 5 ml 5% sulfuric acid and made up to the mark with distilled water.

The solution contains 0.0, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 1.0, 1.5, 2.0, 4.0, 6.0 and 8.0 mg/liter phosphorus respectively. A reagent blank was prepared by taking 5 ml of distilled water and treated as before.

The yellow to yellowish color was pipette off and the absorbance was measured at 420 nm by spectrophotometer machine.

Calculation: The amount of Phosphorus content in the stock solution of wheat grain was calculated by using the standard curve of phosphorus. Finally, the amount of phosphorus present in the wheat grain was determined using the formula given below:

Amount of phosphorus (mg 100 g^{-1} of wheat grain)

$$= \frac{\text{Weight of phosphorus obtained}}{\text{Weight of wheat grain}} \times 100$$

ix. Determination of Calcium content:

Calcium content of wheat grain was determined by Colorimetric method following Stern, J. and Lewis, W.H.P. (1957).

Equipments: i) Spectrophotometer, ii) Volumetric flask, iii) Pipette, iv) Electric balance and v) Test tube.

Reagent:

1. Buffer solution (p^H=10):

   a) 20 g of ammonium chloride was dissolved in 200 ml of distilled water and mixed well.

   b) 150 ml of ammonium hydroxide (NH_4OH) solution was prepared.

   Then solution a) and b) mixed in 1 (one) liter volumetric flask and made up to the mark with distilled water maintaining the p^H 10.

2. Color reagent: 187.5 mg of O-Cresolphthalein Complexon (OCPC) was dissolved in 150 ml distilled water in 500 ml volumetric flask. 4.20 g of 8-Hydroxyquinoline was added to it and mixed well. Then 10 ml of hydrochloric acid (HCl) was added. 250 ml distilled water was added and mixed well. Finally the volume was made up to the mark with distilled water.
3. Standard Calcium solution: 100 ppm calcium solution was used as standard. The solution contains 100 mg L^{-1} calcium.

Procedure:

1 ml of the stock solution was pipette into different test tube. 0.25 ml color reagent and 3 ml buffer solution were added and shaken very well. The absorbance of the solution was measured at 570 nm in a spectrophotometer.

The standard curve of calcium was prepared. 10 ml of 100 ppm standard solution was taken in a 100 ml volumetric flask and made up to the mark with distilled water. Then the concentration of the solution was 10 ppm i.e. 10 mg Ca $liter^{-1}$. From this 10 ppm solution 0.0, 0.05, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of solution was taken in different test tubes and made the volume up to 1 ml with distilled water. The solution contains 0.0, 0.5, 1.0, 2.0, 4.0, 6.0, 0.8 and 1.0 mg Ca $liter^{-1}$ respectively.

A reagent blank was prepared by taking 1 ml distilled water and treated as before.

The violet color was pipette off and the absorbance was measured at 570 nm by spectrophotometer.

Calculation: The amount of calcium content in the stock solution of wheat grain was calculated by using the standard curve of calcium. Finally, the amount of calcium present in the grain was determined using the formula given below:

Amount of calcium (mg 100 g^{-1} of wheat grain)

$$= \frac{\text{Weight of calcium obtained}}{\text{Weight of wheat grain}} \times 100$$

x. Determination of Zinc content:

Zinc content in wheat grain was determined using atomic absorption spectrophotometer following the method of Jackson (1973).

Equipments: i) Beaker, ii) Volumetric flask, iii) Pipette, iv) Electric balance and v) Atomic absorption spectrophotometer

Standard zinc solution: 100 ppm zinc solution was used as standard. The solution contains 0.1 mg Zn ml^{-1}.

Procedure: The atomic absorbance of each of the wheat grain solutions was taken for zinc with the help of an atomic absorption spectrophotometer using hollow cathode at 213.9 nm.

A standard curve of zinc was prepared by taking 0.0, 1.0, 2.0, 3.0 and 4.0 ml of standard (0.1 mg Zn ml^{-1}) zinc solution in 100ml volumetric flask separately and made up to the mark with deionized water. The concentration of the standard solutions was 0.0, 1.0, 2.0, 3.0 and 4.0 ppm of zinc respectively. A reagent blank was taken with distilled water. The atomic absorbance of the solutions was taken at 213.9 nm and standard curve was prepared by plotting the data.

Calculation: The amount of zinc in the stock solution of wheat grain was calculated from the standard curve of zinc. Finally, the amount of zinc present in the grain was determined using the formula given below:

Amount of zinc (mg 100 g^{-1} of wheat grain)

$$= \frac{\text{Weight of zinc obtained}}{\text{Weight of wheat grain}} \times 100$$

3.9 Data analysis technique

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The significance of the difference among the treatments means were estimated by the Duncan's Multiple Range Test (DMRT) at 1% and 5% level of probability (Gomez and Gomez 1984) using the computer based software MSTAT-C developed by Russel (1986).

CHAPTER 4

RESULTS

CHAPTER 4
RESULTS

This chapter comprised with presentation and discussion of the results obtained from the study to observe the effect of sowing time, variety and micronutrients on the growth of wheat plants. The effects of varieties, sowing time and micronutrients and their interaction on growth contributing characters have been presented in Tables and Figures. Summary of mean square values at different parameters are also given at appendices from VI to XIIIB.

4.1 Growth Parameters

Asseng *et al.* (2011); Chapman *et al.*(2012) suggested that it is evident that heat stress adversely affects the growth and development of wheat plants. Such effects can be managed principally through producing appropriate plant genotypes together with adjustment of relevant agronomic practices.

4.1.1 Total Dry Matter

Effect of sowing time

Significant variations for total dry matter (TDM) of wheat variety at all the growth stages were due to different sowing dates in both the years. TDM decreased with late seeding condition. At all the growth stages, the highest TDM was observed in 25th November sowing in both the years. The lowest TDM was recorded in 25th December sowing in both the years. Similar finding was observed by Ahmed *et al*. (2010).

Total dry matter gradually increased at all the successive growth stages due to more accumulation of dry matters the plant got optimum space and thereby intercepted more solar radiation and assimilated more CO_2 compared to late seeding.

Effect of variety

TDM of two varieties of wheat increased as the age of the plant increased up to the physiological maturity stage. Significant variation was observed in terms of TDM at all growth stages in both the years. Different varieties showed different TDM at different growth stages. The results obtained on TDM with different varieties might be due to cause of genetical characters and or nutrient availability, nutrient uptake capacity of the varieties that helps to increase dry weight plant^{-1}. Similar finding was observed by Al- Musa *et al.* (2012). The highest TDM was found in variety V_2 in both the years at all growth stages. The lowest value was observed in variety V_1.

The genotype BARI Gom 28 (V_2) had the highest efficiency on dry matter accumulation (1547.105 gm^{-2} and 1530.217 gm^{-2}) at physiological maturity stage in both the years followed by BARI Gom 26 (V_1) were 1508.709 gm^{-2} and 1455.211 gm^{-2} respectively. This might be due to genetical differences and morphological parameters as BARI Gom 28 (V_2) accumulated maximum dry matter than the variety BARI Gom 26 (V_1) produced the lowest total dry matter in both the reason at all the growth stages.

Effect of micronutrients

Micronutrients levels significantly influenced the total dry matter production at all the growth stages in both the seasons. Combination of B 1.25 kg ha^{-1} and Zn 5.30 kg ha^{-1} (M_3) gave the highest result which was statistically identical with Zinc (5.30 kg ha^{-1}) (M_2). The lowest value was observed in control treatment in both the years. The highest total dry matter was obtained up to physiological maturity stage in both the seasons when combination of B 1.25 kg ha^{-1} and Zn 5.30 kg ha^{-1} (M_3) was applied followed by Zn (5.30 kg ha^{-1}) (M_2) and B (1.25 kg ha^{-1}) (M_1)

compared to control treatment. This was might be due to high response to micronutrients and its use efficiency by the crop.

Interaction effect of sowing time and variety

TDM was significantly affected by the interaction of sowing date and variety all the successive growth stages in both the seasons except CRI stage in 1st year and CRI and Booting stage in 2nd year (Figure 2 and Figure 3). The highest TDM was observed in treatment combination of (D_1V_2) 25th November with BARI Gom 28 (V_2). The lowest TDM was found in treatment combination of (D_3V_1) 25th December with BARI Gom 26 (V_1) at all growth stages in both the years.

At physiological maturity stage BARI Gom 28 (V_2) produced the highest total dry matter (1648.004 gm^{-2} and 1624.104 gm^{-2}) in both the growing reason in 25th November (Appendix XIV). This was might be due to varietal response to sowing date and more uptakes of available nutrients and less competition among the plants for air and solar area ratio radiation.

Interaction effect of sowing time and micronutrients

Interaction effect of different levels of micronutrients and sowing time showed significant differences on TDM of wheat at different growth stages in both the years except CRI stage in 2nd year (Figure 4, Figure 5 and Appendix XV). The highest TDM was observed in treatment combination D_1M_3 at all the growth stages both the experimental seasons while the corresponding lowest TDM was found from treatment combination D_3M_0.

Interaction effect of variety and micronutrients

Interaction effect of improved wheat variety and micronutrients showed significant differences on TDM wheat at all the growth stages in both the years except booting stage in 1st year (Figure 6, Figure 7 and Appendix XVI). Results showed that the highest TDM was obtained from V_2M_3 at all the growth stages. On the other hand the lowest TDM was observed with V_1M_0. Total dry matter increased slowly up to booting stage but after that it increased rapidly with the progress towards the growth period in all the micronutrients treatments of both the cultivars and the years.

Interaction effect of variety, sowing time and micronutrients

Interaction effect of improved wheat variety, sowing time and micronutrients showed significant differences on TDM of wheat at all the growth stages in both the years except booting and heading stage in 2nd year (Table 1a and Table 1b). Results showed that the maximum TDM of wheat was obtained from $D_1V_2M_3$ at all the growth stages. On the other hand the minimum TDM of wheat obtained from $D_3V_1M_0$

Table 1a. Interaction effect of late seeding, variety and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat in 1st year

Parameter / Interaction	1st year TDM (gm^{-2})					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
$D_1V_1M_0$	7.682jk	39.978jkl	187.590 o	570.154 no	882.716 opq	1105.87no
$D_1V_1M_1$	9.252 e-h	46.695 g-j	290.410 j	764.302k	1187.57jk	1452.901jk
$D_1V_1M_2$	9.937 a-f	53.107 b-g	421.341 f	985.661f	1493.306ef	1769.615fg
$D_1V_1M_3$	10.897ab	59.765ab	539.774ab	1193.209a	1801.881ab	2114.18ab
$D_1V_2M_0$	7.887ijk	40.279jkl	209.187n	603.079n	906.287op	1129.408no
$D_1V_2M_1$	9.361 d-h	47.844 f-i	320.720i	801.382jk	1223.61ij	1494.821ij
$D_1V_2M_2$	10.008 a-f	54.005 a-f	435.534f	1005.583ef	1527.831de	1807.937ef
$D_1V_2M_3$	**11.070 a**	**61.019 a**	**548.701a**	**1222.549a**	**1848.201a**	**2159.85a**
$D_2V_1M_0$	7.259 k	39.274 kl	134.846q	488.367p	798.989qr	992.36pq
$D_2V_1M_1$	8.885 f-i	44.821 i-l	268.862k	697.995lm	1078.723lm	1335.811l
$D_2V_1M_2$	9.717 b-h	50.852 d-i	393.334g	915.841gh	1386.49g	1681.002gh
$D_2V_1M_3$	10.522 a-d	57.955abc	519.736c	1129.632bc	1725.668b	2037.207bc
$D_2V_2M_0$	7.485 k	39.521 kl	164.658p	546.528o	841.422pq	1048.04op
$D_2V_2M_1$	9.067fgh	45.691 h-k	282.775jk	750.032kl	1116.57kl	1377.561kl
$D_2V_2M_2$	9.827 b-g	52.017 c-h	404.668g	960.551fg	1416.99fg	1702.332fgh
$D_2V_2M_3$	10.711abc	58.964abc	530.164bc	1174.989ab	1755.945ab	2055.603ab
$D_3V_1M_0$	6.823 k	37.865 l	105.396r	432.847q	699.879s	902.783q
$D_3V_1M_1$	8.610hij	43.863 i-l	228.917m	658.145m	962.957no	1207.844mn
$D_3V_1M_2$	9.509 d-h	49.234 e-i	347.928h	849.83ij	1290.564hi	1589.637hi
$D_3V_1M_3$	10.295 a-e	55.806 a-e	457.321e	1055.121de	1599.949cd	1915.302de
$D_3V_2M_0$	6.990 k	38.056 l	118.171r	463.305pq	738.846rs	951.424pq
$D_3V_2M_1$	8.708 g-j	44.044 i-l	247.057l	676.372m	1017.23mn	1282.955lm
$D_3V_2M_2$	9.588 c-h	49.963 d-i	356.956h	886.181hi	1329.03gh	1612.986h
$D_3V_2M_3$	10.402 a-e	56.932 a-d	499.854d	1082.019cd	1625.261c	1942.343cd
LS	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.10	5.82	1.97	2.84	3.21	3.18

Table 1b. Interaction effect of late seeding, variety and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat in 2^{nd} year

Parameter / Interaction	2nd year TDM (gm^{-2})					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
$D_1V_1M_0$	7.51mn	37.681mn	154.45	465.557	798.106no	1066.283no
$D_1V_1M_1$	8.959g-j	46.173g-k	289.043	675.781	1110.106ij	1388.029jk
$D_1V_1M_2$	9.845c-f	51.998b-g	410.003	904.735	1423.792ef	1711.326fg
$D_1V_1M_3$	10.7ab	58.888a	522.72	1091.424	1773.614a	2063.21ab
$D_1V_2M_0$	7.645 lmn	38.628lmn	175.202	493.441	860.498mn	1128.35mn
$D_1V_2M_1$	9.202f-i	46.782f-k	309.983	714.921	1180.603hi	1470.789ij
$D_1V_2M_2$	9.91b-f	52.687b-f	429.832	914.806	1482.268de	1776.293ef
$D_1V_2M_3$	**10.936a**	**59.939a**	**536.867**	**1114.691**	**1819.25a**	**2120.983a**
$D_2V_1M_0$	6.703op	36.752mn	124.176	397.027	723.886opq	974.703o
$D_2V_1M_1$	8.484ijk	43.777i-l	239.242	585.004	1015.328jkl	1290.636kl
$D_2V_1M_2$	9.594d-g	50.084d-h	359.733	784.698	1316.429fg	1600.786gh
$D_2V_1M_3$	10.375a-d	56.919abc	504.154	1013.187	1642.175bc	1955.257bcd
$D_2V_2M_0$	7.262no	37.452mn	145.89	433.626	765.754nop	1031.116no
$D_2V_2M_1$	8.687h-k	44.97h-k	255.445	651.511	1079.505ijk	1362.679jk
$D_2V_2M_2$	9.69d-g	50.965c-h	398.533	881.685	1402.975ef	1698.049fg
$D_2V_2M_3$	10.498abc	57.878ab	512.967	1079.994	1715.734ab	2038.316abc
$D_3V_1M_0$	6.211p	35.534n	95.636	333.524	616.353q	844.763p
$D_3V_1M_1$	8.071klm	41.74k-n	203.973	537.831	920.4lm	1197.945lm
$D_3V_1M_2$	9.323fgh	48.152f-j	321.586	754.819	1225.868gh	1518.289hi
$D_3V_1M_3$	10.179a-e	54.901a-e	450.349	957.958	1539.069cd	1851.307de
$D_3V_2M_0$	6.535op	36.383n	116.786	370.279	679.898pq	943.602op
$D_3V_2M_1$	8.334jkl	42.792j-m	215.935	560.42	978.426kl	1266.973kl
$D_3V_2M_2$	9.467efg	49.088e-i	339.963	776.961	1291.324g	1588.469ghi
$D_3V_2M_3$	10.302a-d	55.829a-d	462.287	978.891	1604.644c	1936.98cd
LS	0.010	0.010	NS	NS	0.010	0.010
CV	3.60	5.30	2.14	3.15	3.88	3.49

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

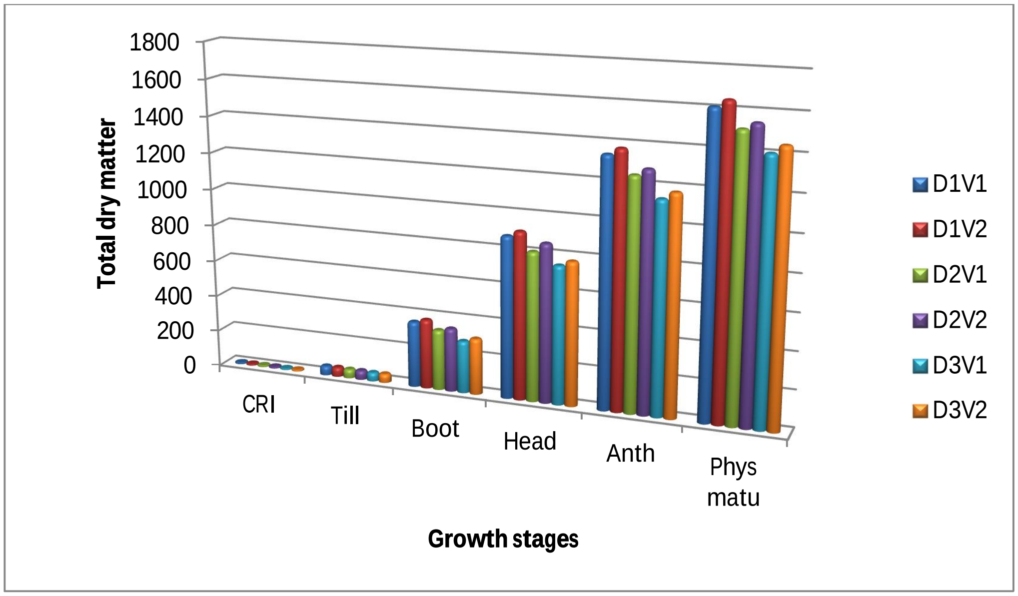


Figure 2: Interaction effect of late seeding and variety on total dry matter (g m^{-2}) at different growth stages of wheat in 2015 - 2016

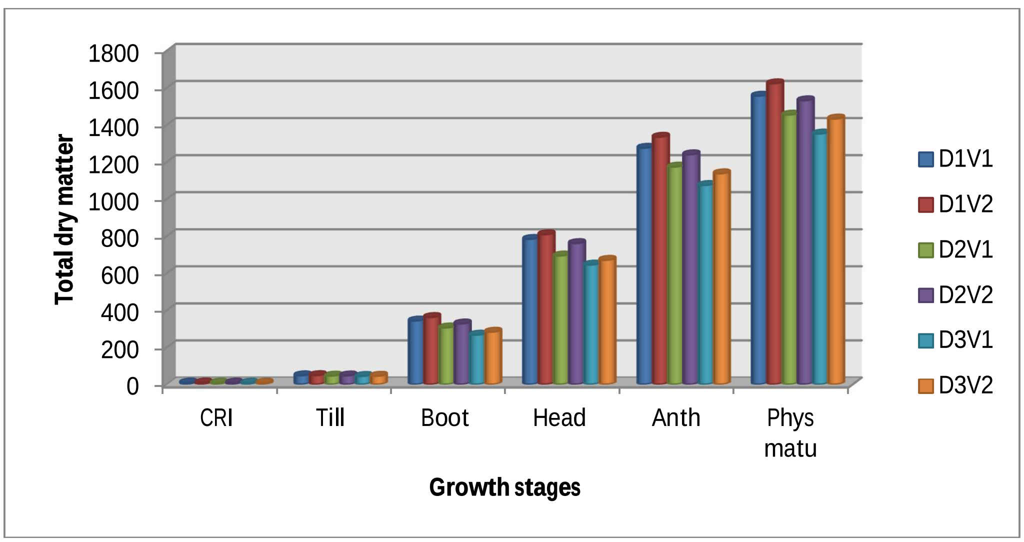


Figure 3: Interaction effect of late seeding and variety on total dry matter (g m^{-2}) at different growth stages of wheat in 2017 - 2018

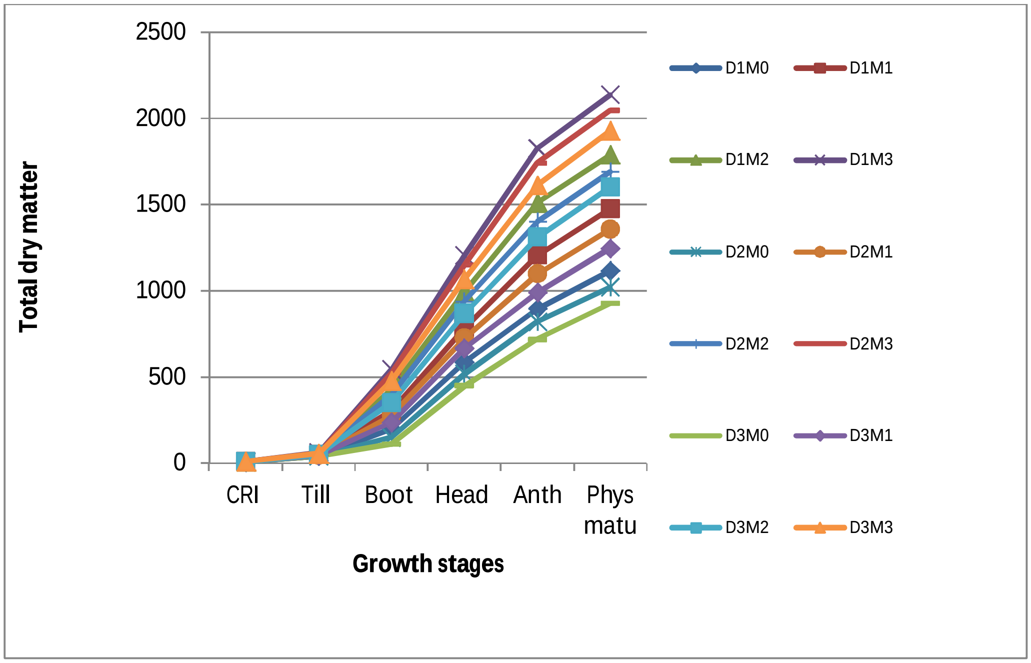


Figure 4: Interaction effect of late seeding and micronutrient on total dry matter ($g\ m^{-2}$) at different growth stages of wheat in 2015 - 2016

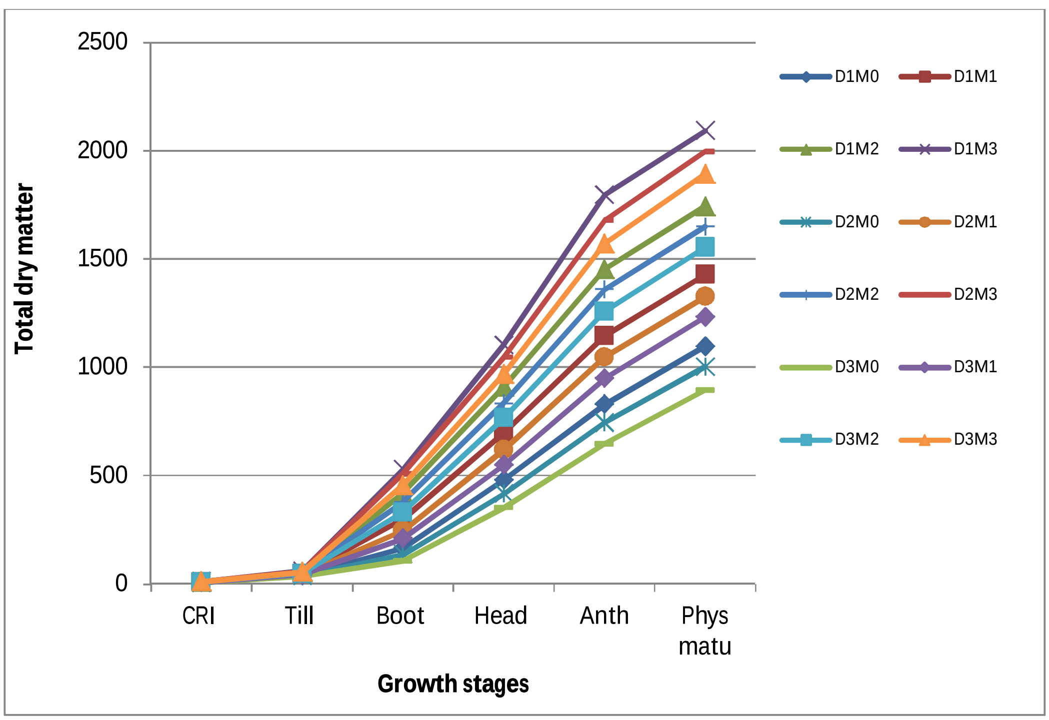


Figure 5: Interaction effect of late seeding and micronutrient on total dry matter ($g\ m^{-2}$) at different growth stages of wheat in 2017 - 2018

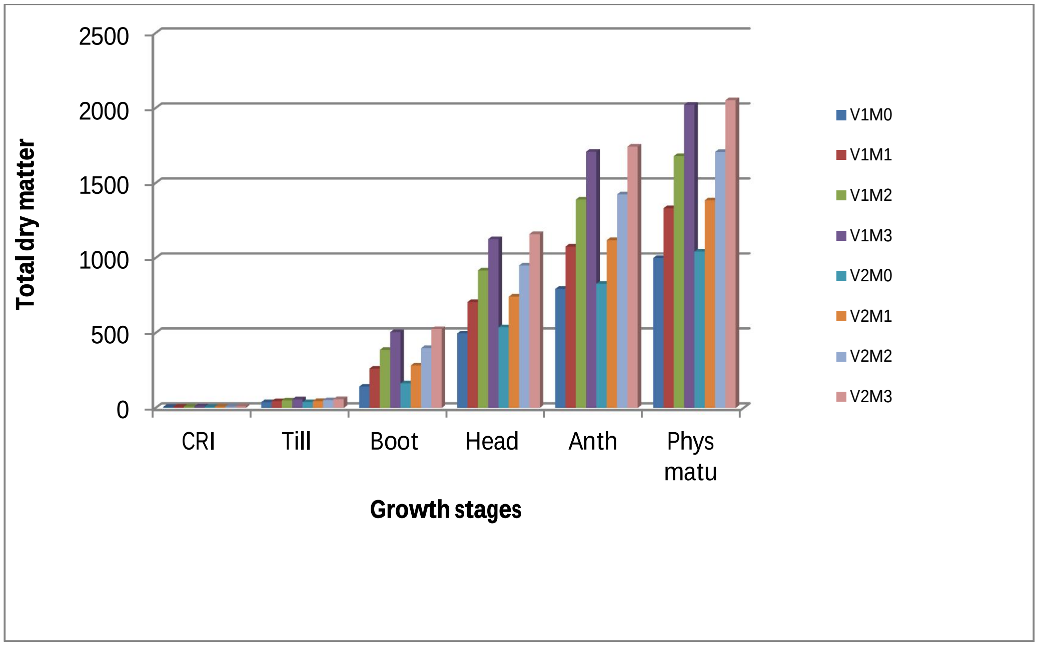


Figure 6: Interaction effect of variety and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat in 2015 - 2016

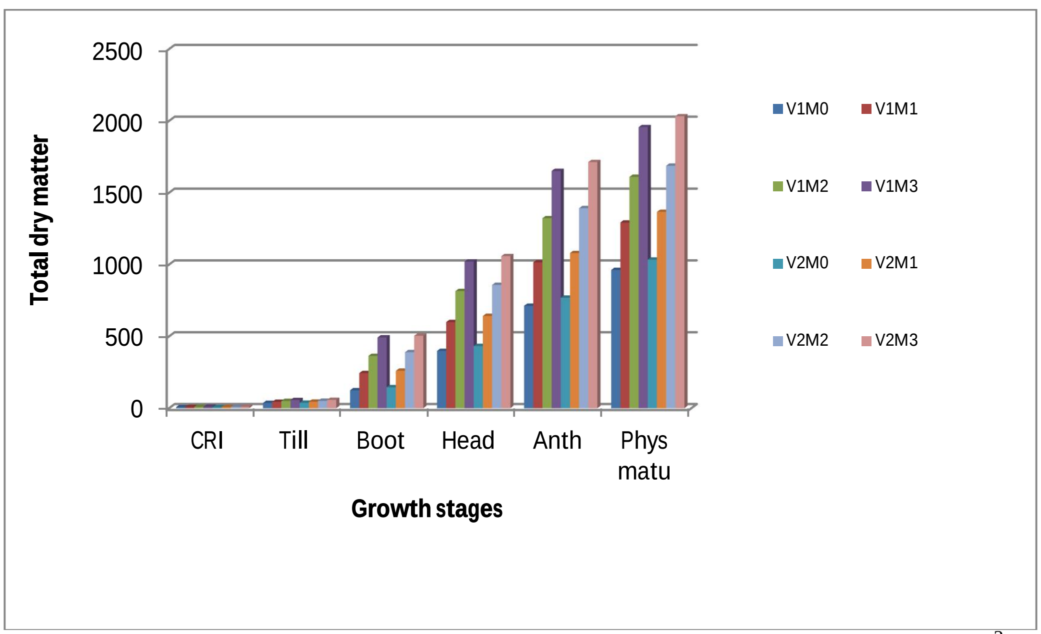


Figure 7: Interaction effect of variety and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat in 2017 - 2018

4.1.2 Leaf Area Index (LAI)

Effect of sowing time

Leaf area index of wheat varied significantly due to different sowing date treatments at different growth stages like CRI stage, tillering stage, booting stage, heading stage, anthesis stage and physiological maturity stage in both the experimental years. The highest leaf area index was obtained from sowing of D_1 and the lowest leaf area index was recorded from sowing of D_3. Heat stress mostly affects the plant meristems and reduces plant growth by promoting leaf senescence and abscission, and by reducing photosynthesis (Kosova *et al.* 2011).

There was a general trend of declining leaf area index as the age of the plant advanced specially at anthesis stage in both the cropping years.

25^{th} November showed the highest value (4.202 and 4.074) in respect of leaf area index at anthesis stage followed by 25^{th} December (3.84 and 3.697) in both the cropping years.

Effect of variety

Leaf area index increased gradually from CRI stage to anthesis stage indicating that leaf expansion continued increasing up to anthesis stage. Analysis of variance revealed that the cultivar differences were significant for all the growth stages. Significant variations were observed in both the years. Cultivar BARI Gom 28 (V_2) showed higher LAI at all the growth stages than that of cultivar BARI Gom 26 (V_1) in both the seasons. Similar finding was observed by Wheat Research Centre (2003).

Green leaf area is the source of food production of green plants. Leaf number and size normally increased very slowly up to a certain period and then there was a rapid increase in number and area of leaf per plant. All the cultivars starting from a lower value leaf area index and reached their peaks at anthesis stage and there after declined. The maximum peak for leaf area index was observed for variety BARI Gom 28 (V_2) in both the experimental years at anthesis stage compared to BARI Gom 26 (V_1).

Effect of micronutrient

In all the treatments of both the cultivars and years LAI increased with the progress towards the growth period and reached a peak at anthesis stage. However, it showed gradual decrease in the later stage of plant growth.

Leaf area index varied significantly due to micronutrient levels at all the growth stages in both the seasons. Among the micronutrient levels, all showed first peak at the anthesis stage and then declined up to physiological maturity stage. This was because it was the transition period from vegetative to reproductive phase. Among the treatments, combination with (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) gave the highest leaf area index followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) and the lowest was found in control treatment.

Interaction effect of sowing time and variety

Different treatment combinations source of sowing time and variety had no significant influence on the leaf area index of wheat at CRI, tillering and heading stage in 1st year and CRI, booting, anthesis and physiological maturity stage in 2nd year (Figure 8, Figure 9 and Appendix XVII). The highest leaf area index was recorded in the treatment combination of D_1V_2 and the lowest leaf area index was recorded from D_3V_1 in all growth stages both the years. The highest leaf area index was recorded form BARI Gom 28 (V_2) in 25th November (D_1) followed by 25th December (D_3) with the BARI Gom 26 (V_1).

Interaction effect of sowing time and micronutrient

Different treatment combinations source of sowing time and micronutrient had significant influence on the leaf area index of wheat at all the growth stages except CRI stage in 1st year and CRI and tillering stage in 2nd year (Figure 10, Figure 11 and Appendix XVIII). From the result the highest leaf area index was recorded in the treatment combination of D_1M_3 at all the successive growth stages in both the seasons on the contrary the lowest leaf area index was recorded from D_3M_0.

Interaction effect of variety and micronutrient

LAI varied significantly due to the interaction of variety and micronutrient at all sampling dates in both the years. At all growth stages in both the years the highest value was counted in the treatment combination of V_2M_3.The lowest LAI was obtained in V_1M_0 treatment combination at all sampling dates in both the years (Figure 12, Figure 13 and Appendix XIX).

Interaction effect of sowing time, variety and micronutrient

Different treatment combinations source of sowing time, variety and micronutrient had significant influence on the leaf area index of wheat at all the successive growth stages of wheat (Table 2a and Table 2b). The highest leaf area index was recorded in the treatment combination of $D_1V_2M_3$ and the lowest leaf area index was recorded from $D_3V_1M_0$.

Table 2a. Interaction effect of late seeding, variety and micronutrient on leaf area index at different growth stages of wheat in 1st year

Parameter / Interaction	1st year LAI					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
$D_1V_1M_0$	0.198 f-i	0.989lmn	1.937 ij	2.13j	3.164jkl	2.319jkl
$D_1V_1M_1$	0.264 a-g	1.219g-j	2.557 e-h	2.794d-h	3.887fgh	2.778e-h
$D_1V_1M_2$	0.296 a-d	1.397c-f	2.864a-e	3.11a-e	4.496b-e	3.073a-f
$D_1V_1M_3$	0.331 ab	1.542ab	3.203a	3.475a	5.116a	3.419ab
$D_1V_2M_0$	0.208 e-i	1.036klm	2.02ij	2.218ij	3.211i-l	2.343i-l
$D_1V_2M_1$	0.267 a-g	1.246ghi	2.587e-h	2.814d-h	3.942fgh	2.805e-h
$D_1V_2M_2$	0.298 a-d	1.415b-e	2.884a-e	3.13a-d	4.545b-e	3.096a-e
$D_1V_2M_3$	**0.333 a**	**1.565a**	**3.24a**	**3.506a**	**5.252a**	**3.449a**
$D_2V_1M_0$	0.177 hi	0.958mno	1.786j	2.019j	3.032l	2.13lm
$D_2V_1M_1$	0.249 b-h	1.18hij	2.445fgh	2.689fgh	3.721ghi	2.691f-j
$D_2V_1M_2$	0.287 a-e	1.316e-h	2.764b-f	3.035b-f	4.253d-g	3.002c-g
$D_2V_1M_3$	0.32 ab	1.505abc	3.099ab	3.394ab	4.918ab	3.34abc
$D_2V_2M_0$	0.189 ghi	0.971mno	1.83j	2.047j	3.07kl	2.262klm
$D_2V_2M_1$	0.255 a-h	1.191hij	2.469fgh	2.712e-h	3.789gh	2.717e-i
$D_2V_2M_2$	0.29 a-d	1.339d-g	2.792b-f	3.047b-f	4.359c-f	3.033b-f
$D_2V_2M_3$	0.323 ab	1.525abc	3.135ab	3.412ab	4.989ab	3.362abc
$D_3V_1M_0$	0.156 i	0.856o	1.716j	1.916j	2.905l	1.93m
$D_3V_1M_1$	0.228 d-i	1.107jkl	2.268hi	2.499hi	3.564h-k	2.592h-k
$D_3V_1M_2$	0.274 a-f	1.279fgh	2.655d-g	2.902c-g	4.026e-h	2.881d-h
$D_3V_1M_3$	0.311 abc	1.453a-d	3.01a-d	3.262abc	4.737a-d	3.219a-d
$D_3V_2M_0$	0.168 i	0.88no	1.741j	1.961j	2.927l	2.034lm
$D_3V_2M_1$	0.235 c-i	1.128ijk	2.379gh	2.608gh	3.601hij	2.618g-k
$D_3V_2M_2$	0.279 a-e	1.295e-h	2.689c-g	2.934c-g	4.136efg	2.918d-h
$D_3V_2M_3$	0.314 abc	1.46a-d	3.039abc	3.298abc	4.826abc	3.25a-d
LS	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.08	4.33	5.94	5.68	5.31	5.65

Table 2b. Interaction effect of late seeding, variety and micronutrient on leaf area index at different growth stages of wheat in 2nd year

Parameter / Interaction	2nd year LAI					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
$D_1V_1M_0$	0.19f-j	0.979mn	1.835klm	2.058l	3.019klm	2.227mno
$D_1V_1M_1$	0.254a-g	1.196ijk	2.466e-i	2.693f-j	3.773f-j	2.662h-l
$D_1V_1M_2$	0.284a-d	1.347ef	2.778a-e	3.024b-f	4.361cde	2.961c-h
$D_1V_1M_3$	0.319a	1.534ab	3.097a	3.373ab	4.993ab	3.295ab
$D_1V_2M_0$	0.199e-j	1.034lm	1.947jkl	2.144kl	3.089klm	2.248mn
$D_1V_2M_1$	0.256a-g	1.218hij	2.494e-h	2.73f-j	3.853f-j	2.687g-l
$D_1V_2M_2$	0.287a-d	1.382def	2.805a-e	3.051a-f	4.389cde	2.989b-g
$D_1V_2M_3$	**0.322a**	**1.556a**	**3.119a**	**3.401a**	**5.117a**	**3.317a**
$D_2V_1M_0$	0.167hij	0.915no	1.627lmn	1.861lm	2.849m	2.045nop
$D_2V_1M_1$	0.233b-i	1.12jkl	2.346ghi	2.588hij	3.584hij	2.554jkl
$D_2V_1M_2$	0.277a-e	1.31fgh	2.671b-g	2.922d-h	4.103efg	2.864e-j
$D_2V_1M_3$	0.312ab	1.46a-d	3ab	3.269a-d	4.786abc	3.186a-d
$D_2V_2M_0$	0.179g-j	0.962mno	1.744lmn	1.995lm	2.945ml	2.136nop
$D_2V_2M_1$	0.245a-h	1.179ijk	2.378f-i	2.639g-j	3.669g-j	2.578i-l
$D_2V_2M_2$	0.279a-e	1.333efg	2.705b-f	2.978c-g	4.227def	2.888d-i
$D_2V_2M_3$	0.314ab	1.492abc	3.023ab	3.305abc	4.899ab	3.227abc
$D_3V_1M_0$	0.15j	0.783p	1.462n	1.702m	2.681m	1.835p
$D_3V_1M_1$	0.215d-j	1.097kl	2.145ijk	2.404jk	3.407jkl	2.444lm
$D_3V_1M_2$	0.266a-f	1.237ghi	2.558d-h	2.826f-i	3.943e-i	2.762g-k
$D_3V_1M_3$	0.298abc	1.423cde	2.899a-d	3.195a-e	4.6bcd	3.1a-f
$D_3V_2M_0$	0.158ij	0.861op	1.573mn	1.802lm	2.754m	1.941op
$D_3V_2M_1$	0.226c-j	1.102kl	2.261hij	2.503ij	3.474ijk	2.483klm
$D_3V_2M_2$	0.268a-f	1.286f-i	2.605c-h	2.87e-h	4.037e-h	2.798f-k
$D_3V_2M_3$	0.302abc	1.44b-e	2.938abc	3.216a-e	4.681a-d	3.137a-e
LS	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.28	3.81	5.74	5.34	5.24	4.78

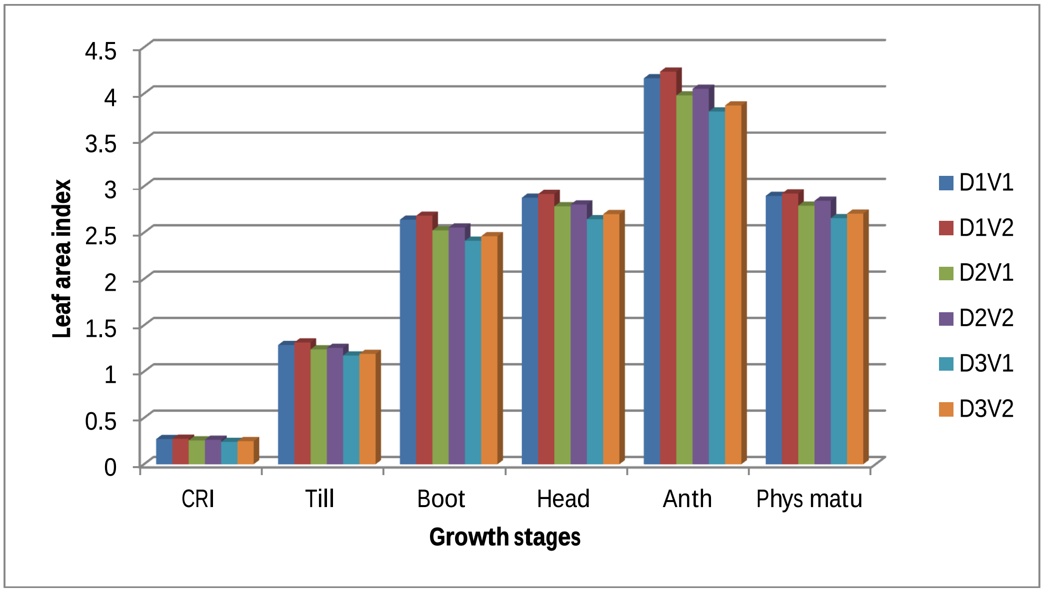


Figure 8: Interaction effect of late seeding and variety on leaf area index at different growth stages of wheat in 2015 - 2016

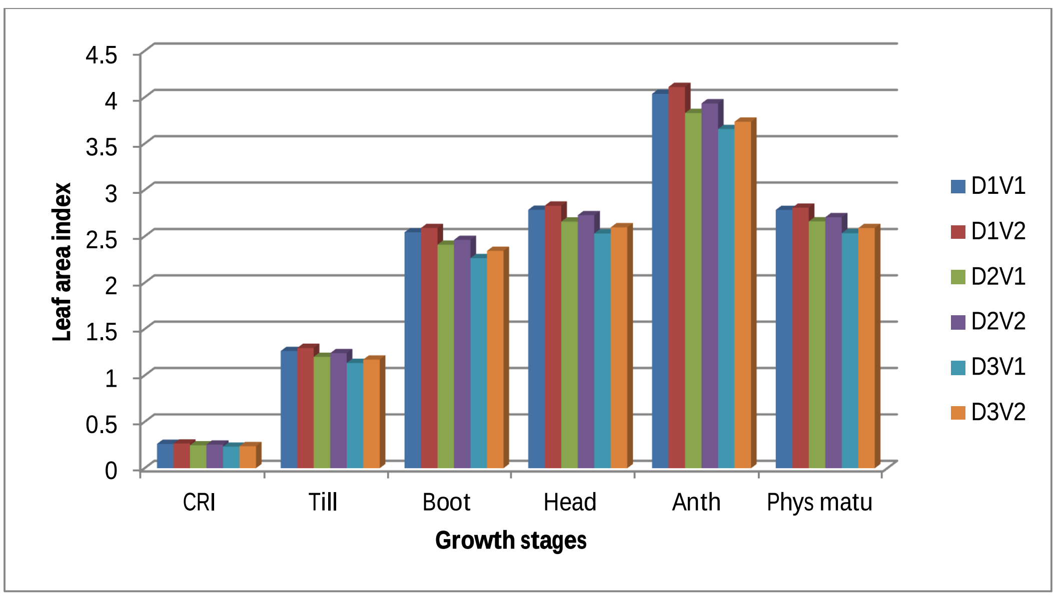


Figure 9: Interaction effect of late seeding and variety on leaf area index at different growth stages of wheat in 2017 - 2018

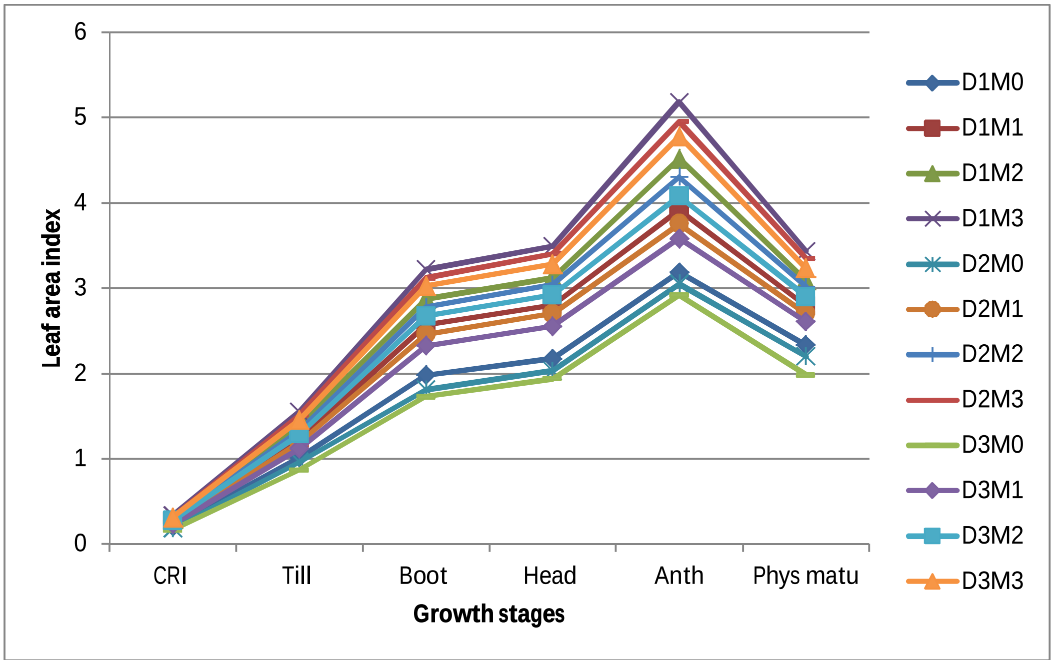


Figure 10: Interaction effect of late seeding and micronutrient on leaf area index at different growth stages of wheat in 2015 - 2016

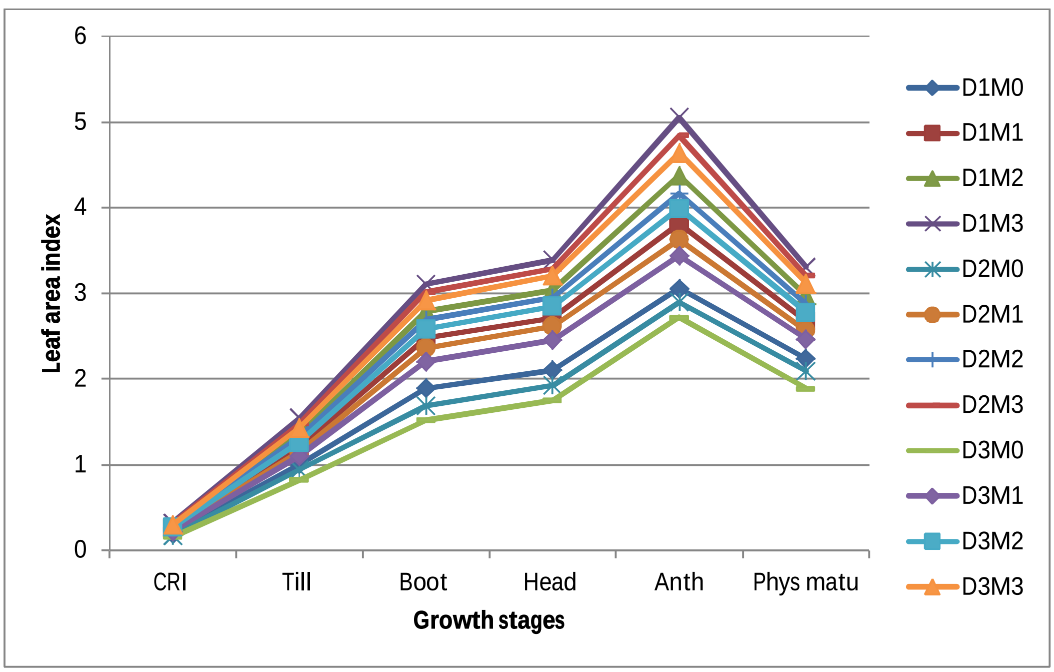


Figure 11: Interaction effect of late seeding and micronutrient on leaf area index at different growth stages of wheat in 2017 - 2018

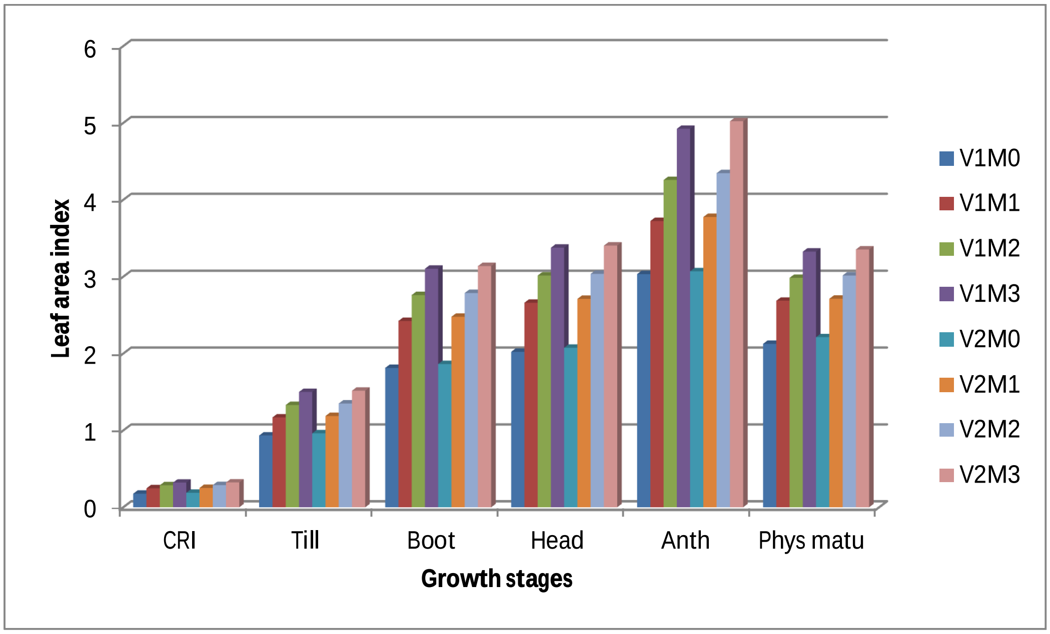


Figure 12: Interaction effect of variety and micronutrient on leaf area index at different growth stages of wheat in 2015 - 2016

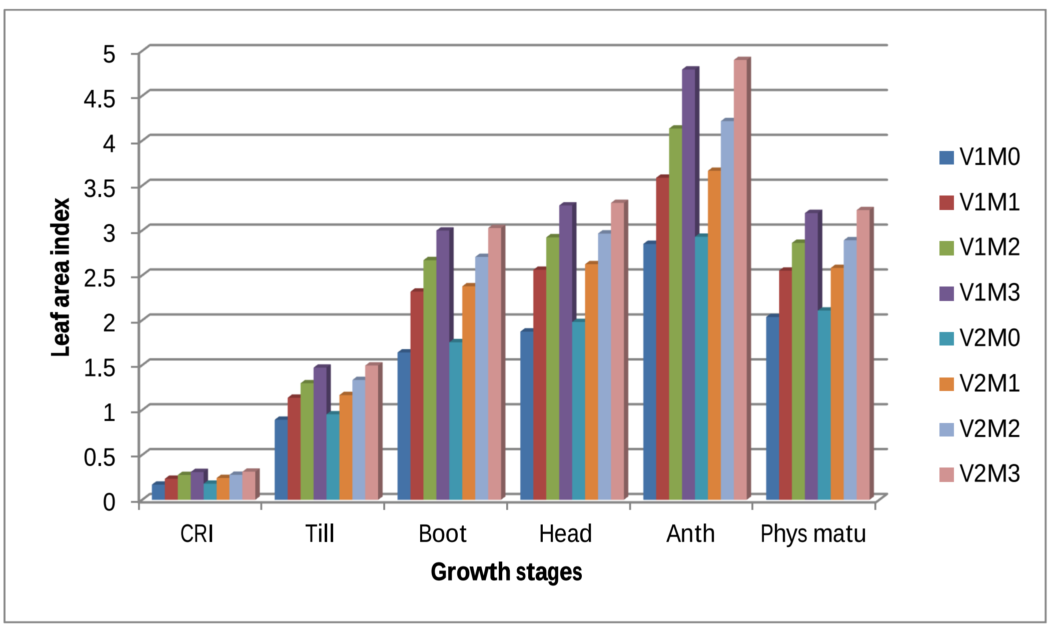


Figure 13: Interaction effect of variety and micronutrient on leaf area index at different growth stages of wheat in 2017 - 2018

4.1.3 Crop Growth Rate (CGR)

Effect of sowing time

Sowing dates had significant effect on crop growth rate at all the growth stages in both the seasons. In the three sowing date crop growth rate gradually increased with the increasing growth period and reached their peak at booting to heading stage in first year and heading to anthesis stage in second year. CGR decreased with the delay in sowing of wheat at tillering and booting stage both the cropping seasons. From the result it can be seen that, due to different sowing dates specially late seeding heat stress condition influence the different growth stage duration of wheat. In 10th December the duration of anthesis to maturity stage become lower and in 25th December the duration of heading, anthesis and maturity stages get lower time compared to 25th November which is optimum date (Appendix IV). Temperatures above 30°C during floret formation cause complete sterility (Saini and Aspinal 1982).

Statistically significant variation was observed on CGR of wheat due to different sowing date. In recording CGR of tillering and booting stage sowing on 25th November (D_1) recorded that CGR as 21.255 and 20.294g m^{-2} day^{-1} respectively which was significantly higher and lowest CGR as 12.412 and 11.513g m^{-2} day^{-1} respectively obtained in 25th December (D_3) both the years.

The highest CGR within the period booting to heading stage and heading to anthesis stage were found in 10th December (D_2) which was statistically identical with 25th November (D_1) in both the years.

Effect of variety

Variety showed significant effect on crop growth rate at all the growth stages in both the seasons except anthesis to physiological maturity stage in second year. The genotype BARI Gom 28 (V_2) produced the highest crop growth rate values in all the growth stages. The highest peak of crop growth rate was

44.566g m^{-2} day^{-1} found on booting to heading stage in BARI Gom 28 (V_2) in 1st year and 43.234 g m^{-2} day^{-1} at heading to anthesis stage gave highest peak in 2nd year. The lowest crop growth rate value was recorded from BARI Gom 26 (V_1) across the growth stages.

Effect of micronutrient

Micronutrients level had significant effect on crop growth rate at all the growth stages in both the cropping seasons. Application combination of (B 1.25 kg ha^{-1} +Zn 5.30 kg ha^{-1}) (M_3) showed the highest crop growth rate followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) and the lowest one was found under control treatment.

The highest peak of crop growth rate was 55.326 g m^{-2} day^{-1} found on booting to heading stage in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in 1st year and 56.602 g m^{-2} day^{-1} at heading to anthesis stage gave highest peak in 2nd year. The lowest crop growth rate value was recorded from control (M_0) across the growth stages both the seasons.

Interaction effect of sowing time and variety

Crop growth rate was significantly influenced due to the interaction of sowing date and variety at all the stages of growth in both the years except crown root initiation to tillering stage in second year. Treatment combination D_1V_2 showed the highest crop growth rate at tillering to booting stage. The minimum value for crop growth rate was recorded from D_3V_1 at tillering to booting stage in both the seasons (Figure 14, Figure 15 and Appendix XX). On the other hand increased progressively with the age of plants up to booting to heading stage in 1st year and heading to anthesis stage in 2nd year thereafter it declined.

Interaction effect of sowing time and micronutrient

Late seeding and micronutrient was significant at all the stage of growth in both the experimental years except CRI to tillering stage and anthesis to physiological maturity stage. At tillering to booting stage the highest crop growth rate values were recorded in 25th November (D_1) at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment on the contrary the lowest crop growth rate was recorded in 25th December (D_3) at control (M_0) treatment both the years (Figure 16, Figure 17 and Appendix XXI).

Interaction effect of variety and micronutrient

CGR was influenced significantly due to the interaction of variety and micronutrient at all growth stages in both the years.

BARI Gom 28 (V_2) gave the highest CGR at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) at all the stages of growth in both of the experimental years except heading to anthesis stage and anthesis to physiological maturity stage in 1st year. On the other hand, BARI Gom 26 (V_1) gave the lowest CGR at control (M_0) during all the sampling stages in both experimental years, respectively except heading to anthesis stage in 1st year (Figure 18, Figure 19 and Appendix XXII).

Interaction effect of sowing time, variety and micronutrient

Interaction effect of sowing time, variety and micronutrient showed significant differences on crop growth rate (CGR) of wheat both the years except tillering to booting stage and booting to heading stage in 2nd year (Table 3a and Table 3b). At tillering to booting stage the highest CGR 32.512 g m^{-2} day^{-1} and 31.795 g m^{-2} day^{-1} were observed from treatment combination $D_1V_2M_3$ on the other hand the lowest CGR observed from treatment combination $D_3V_1M_0$ (3.377 g m^{-2} day^{-1} and 3.005 g m^{-2} day^{-1}) in both the years.

Table 3a. Interaction effect of late seeding, variety and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat 1st year

Parameter / Interaction	1st year CGR(g m^{-2} day^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	2.153j	9.841lm	25.504j	20.838l	7.439j
$D_1V_1M_1$	2.497g-j	16.248i	31.593i	28.218k	8.844f-j
$D_1V_1M_2$	2.878d-h	24.549c	37.621h	33.843hij	9.211e-j
$D_1V_1M_3$	3.258cde	32a	43.562g	40.578efg	10.41b-g
$D_1V_2M_0$	2.159j	11.26k	26.259j	20.214l	7.437j
$D_1V_2M_1$	2.566g-j	18.192g	32.044i	28.149k	9.04f-j
$D_1V_2M_2$	2.933d-g	25.435b	38.003h	34.817hi	9.337e-j
$D_1V_2M_3$	3.33cd	**32.512a**	44.923g	41.71def	10.388b-g
$D_2V_1M_0$	2.134j	4.778o	35.352hi	31.062ijk	7.735ij
$D_2V_1M_1$	2.396ij	11.202k	42.914g	38.073fgh	10.284c-h
$D_2V_1M_2$	2.742f-i	17.124h	52.25de	47.065c	11.78a-d
$D_2V_1M_3$	3.162c-f	23.089d	60.99ab	**59.604a**	12.461abc
$D_2V_2M_0$	2.136j	6.257n	38.187h	29.49jk	8.265g-j
$D_2V_2M_1$	2.441hij	11.854k	46.726fg	36.654gh	10.44a-g
$D_2V_2M_2$	2.813e-i	17.633gh	55.588cd	45.644cd	11.414a-e
$D_2V_2M_3$	3.217cde	23.56d	**64.482a**	58.096ab	11.986a-d
$D_3V_1M_0$	3.104c-f	3.377p	32.745i	26.703k	8.116hij
$D_3V_1M_1$	3.525c	9.253m	42.923g	30.481ijk	9.795d-i
$D_3V_1M_2$	3.972b	14.935j	50.19ef	44.073cde	11.963a-d
$D_3V_1M_3$	4.551a	20.076f	59.78b	54.483b	12.614ab
$D_3V_2M_0$	3.107c-f	4.006p	34.513hi	27.554k	8.503f-j
$D_3V_2M_1$	3.534c	10.151l	42.932g	34.086hij	10.629a-f
$D_3V_2M_2$	4.038b	15.35j	52.923de	44.285cde	11.358a-e
$D_3V_2M_3$	**4.653a**	22.146e	58.216bc	54.324b	**12.683a**
LS	0.010	0.010	0.010	0.010	0.010
CV	6.13	2.11	3.92	5.37	8.70

Table 3b. Interaction effect of late seeding, variety and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2nd year

Parameter / Interaction	2nd year CGR(g m^{-2} day^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	2.012m	7.784	20.74	22.17k	8.939h
$D_1V_1M_1$	2.481jkl	16.191	25.783	28.955ijk	9.264fgh
$D_1V_1M_2$	2.81f-j	23.867	32.982	34.604hi	9.584e-h
$D_1V_1M_3$	3.213c-f	30.922	37.913	45.479def	9.653e-h
$D_1V_2M_0$	2.065lm	9.105	21.216	24.47jk	8.928h
$D_1V_2M_1$	2.505ijk	17.546	26.996	31.046hij	9.673e-h
$D_1V_2M_2$	2.852e-j	25.143	32.332	37.831gh	9.801d-h
$D_1V_2M_3$	3.267cde	**31.795**	38.522	46.971cde	10.058d-h
$D_2V_1M_0$	2.003m	4.371	27.285	32.686hi	10.032d-h
$D_2V_1M_1$	2.353klm	9.773	34.576	43.033efg	11.012b-h
$D_2V_1M_2$	2.699h-k	15.483	42.497	53.173bc	11.374a-f
$D_2V_1M_3$	3.103c-h	22.362	50.903	62.899a	12.523abc
$D_2V_2M_0$	2.013m	5.422	28.774	33.213hi	10.614c-h
$D_2V_2M_1$	2.419j-m	10.524	39.607	42.8efg	11.327a-f
$D_2V_2M_2$	2.752g-k	17.378	48.315	52.129bcd	11.803a-d
$D_2V_2M_3$	3.159c-g	22.754	**56.703**	**63.574a**	12.903ab
$D_3V_1M_0$	2.932d-i	3.005	23.789	28.283ijk	9.137gh
$D_3V_1M_1$	3.367cd	8.111	33.386	38.257fgh	11.102b-g
$D_3V_1M_2$	3.883b	13.672	43.323	47.105cde	11.697a-e
$D_3V_1M_3$	4.472a	19.772	50.761	58.111ab	12.49abc
$D_3V_2M_0$	2.985d-h	4.02	25.349	30.962hij	10.548c-h
$D_3V_2M_1$	3.446c	8.657	34.448	41.801efg	11.542a-e
$D_3V_2M_2$	3.962b	14.544	43.7	51.436bcd	11.886a-d
$D_3V_2M_3$	**4.553a**	20.323	51.66	62.575a	**13.293a**
LS	0.010	NS	NS	0.010	0.010
CV	6.00	2.19	4.53	7.10	7.53

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. NS = Not significant

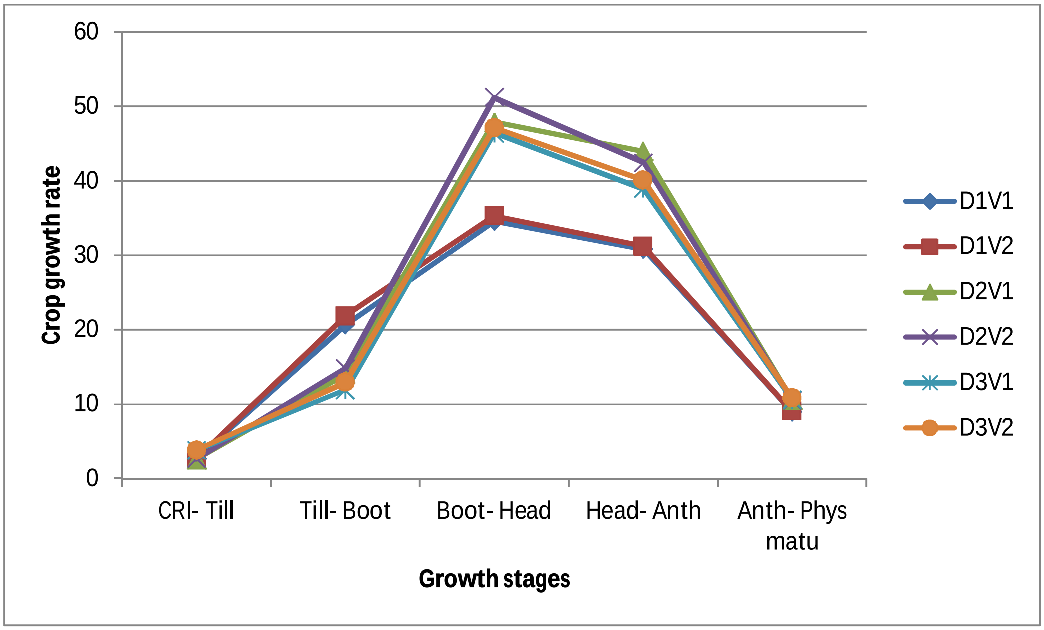


Figure 14: Interaction effect of late seeding and variety on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

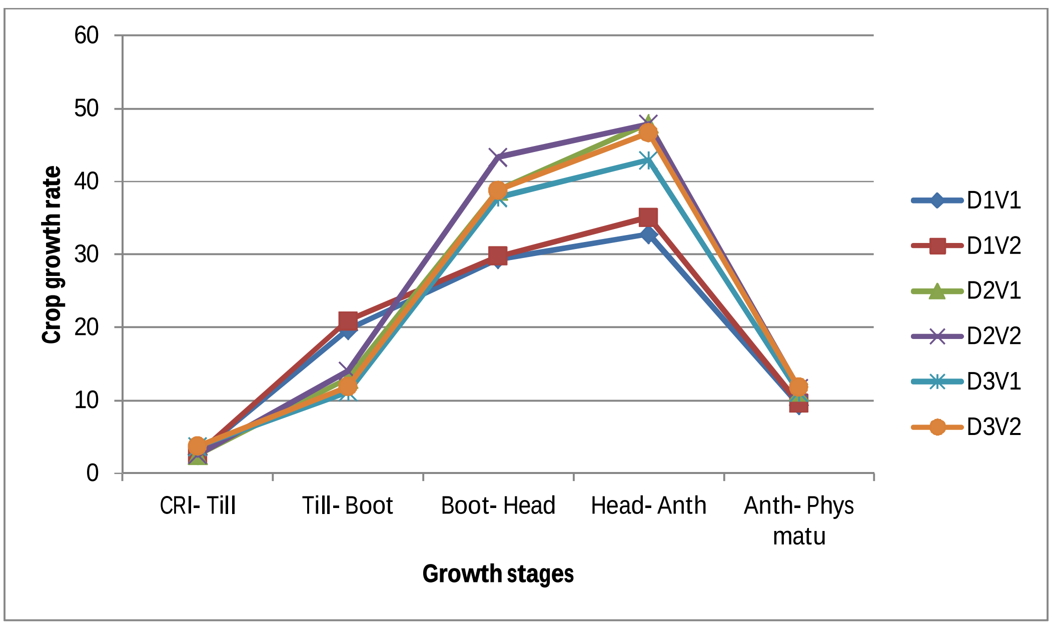


Figure 15: Interaction effect of late seeding and variety on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

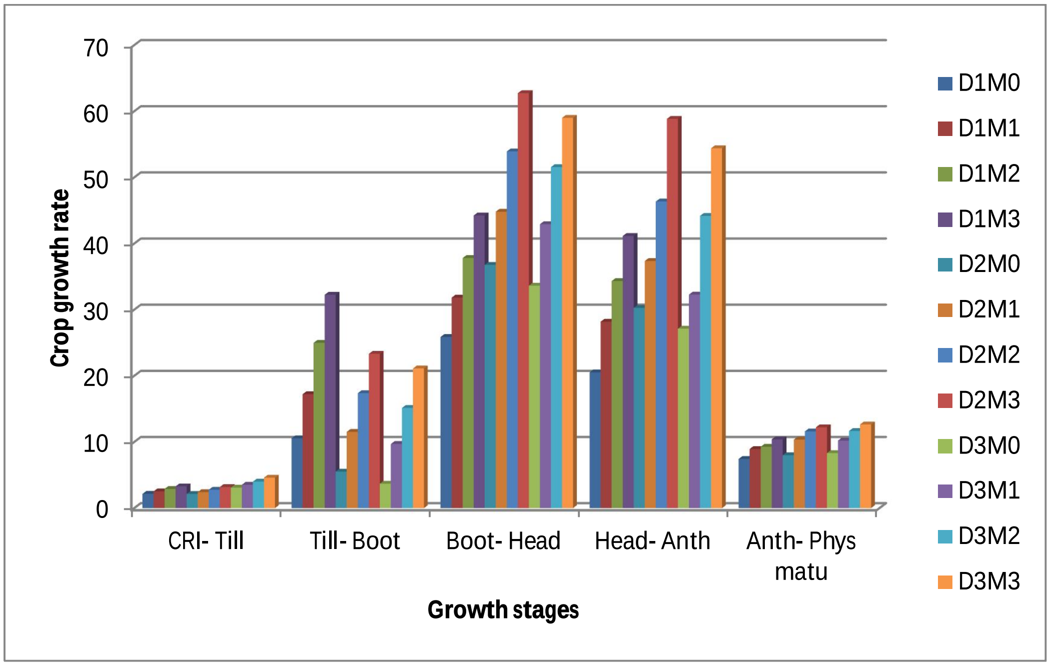


Figure 16: Interaction effect of late seeding and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

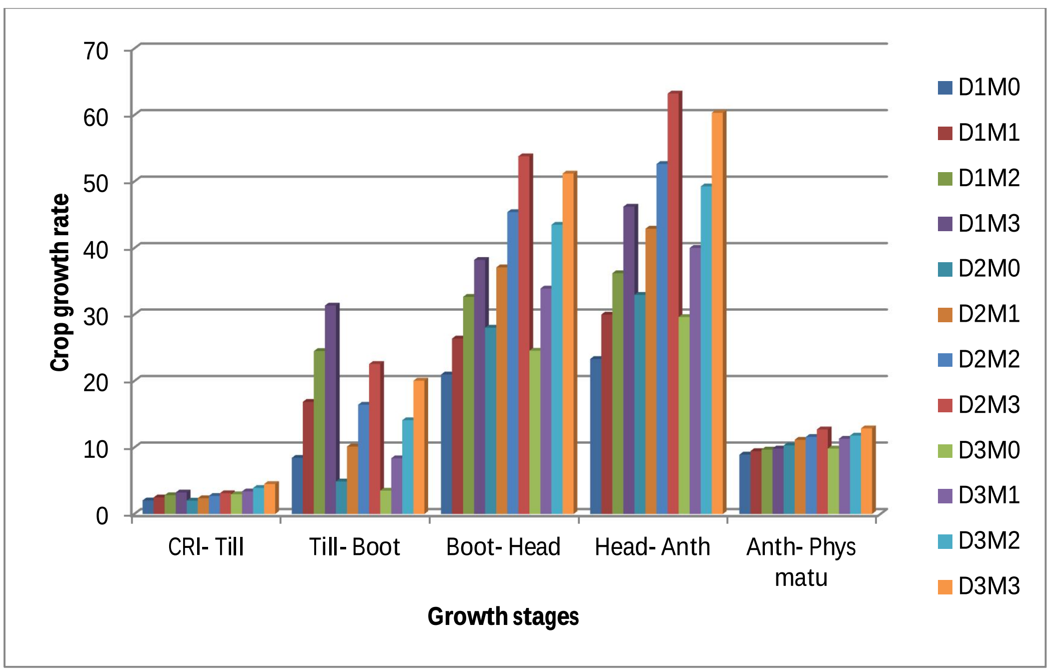


Figure 17: Interaction effect of late seeding and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

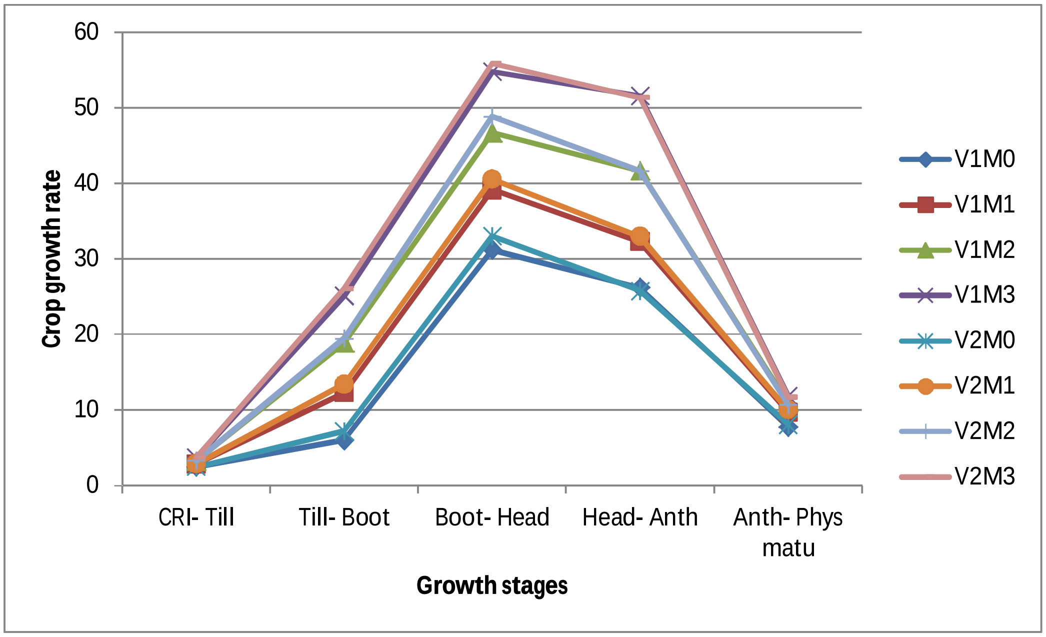


Figure 18: Interaction effect of variety and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

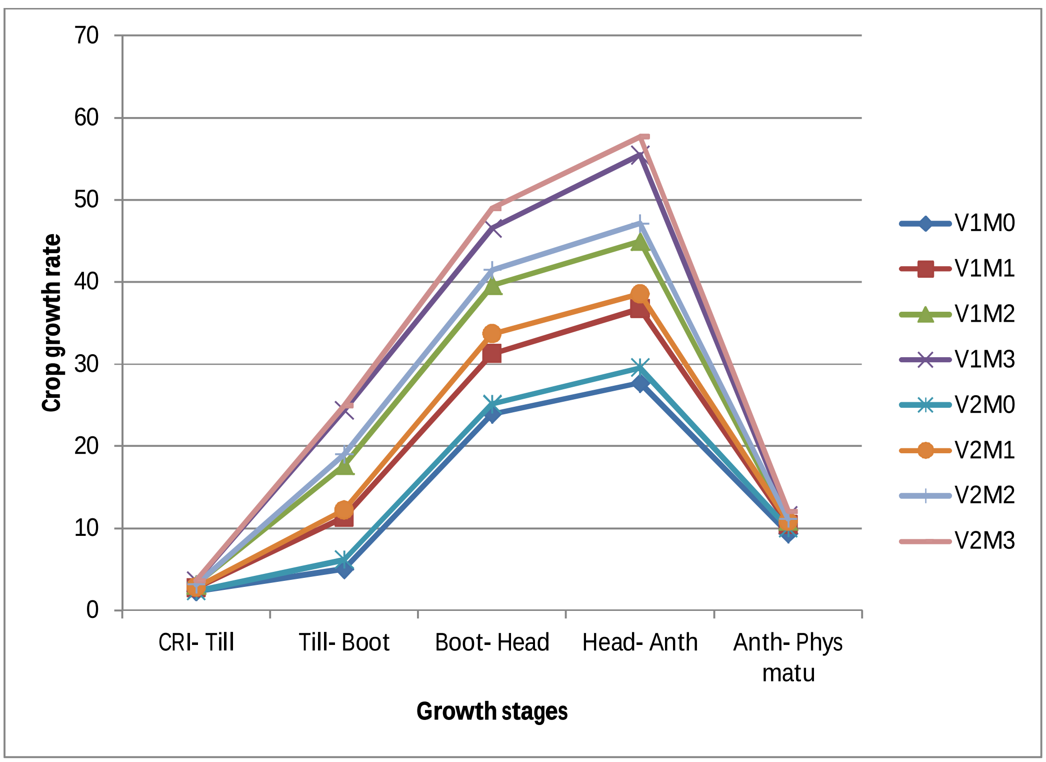


Figure 19: Interaction effect of variety and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

4.1.4 Relative Growth Rate (RGR)

Effect of sowing time

There was a significant effect of sowing date on relative growth rate in both the seasons. The maximum relative growth rate value was recorded in 25^{th} November (D_1) at tillering to booting stage and lowest value was from 25^{th} December (D_3) in both the experimental years because delay in sowing resulted in the reduction in the RGR values of wheat.

Effect of variety

Variety had significant effect on relative growth rate at all the growth stages in both the seasons except CRI to tillering stage and heading to anthesis stage in the 2nd year. The values of relative growth rate of two varieties of wheat were found maximum at crown root initiation to tillering stage and then declined with increasing plant age. Between the genotypes BARI Gom 26 (V_1) gave the highest relative growth rate in 1st year except tillering to booting stage and BARI Gom 28 (V_2) gave in 2nd year except booting to heading stage.

Effect of micronutrient

Relative growth rate varied significantly due to micronutrients level at all the growth stages in both the experimental years. In both the years highest relative growth rate was obtained at crown root initiation to tillering and tillering to booting stage when combination of (B 1.25 kg ha^{-1} +Zn 5.30 kg ha^{-1}) (M_3) was applied and the lowest one was obtained from the control (M_0) treatment at tillering to booting stage.

Interaction effect of sowing time and variety

Significant effect was observed on the relative growth rate due to interaction of sowing date and variety at all the successive growth stages in both the seasons (Figure 20, Figure 21 and Appendix XXIII). The highest value for relative growth rate was recorded in D_1V_2 combination and the lowest one was recorded in D_3V_1 combination at tillering to booting stage.

Interaction effect of sowing time and micronutrient

Interaction effect of sowing date and micronutrients level on relative growth rate was statistically significant at all the successive growth stages in both the seasons except anthesis to physiological maturity stage in 1st year. The highest value was obtained from treatment combination D_1M_3 and the lowest relative growth rate value was obtained from the treatment combination D_3M_0 at tillering to booting stage in both the experimental years (Figure 22, Figure 23 and Appendix XXIV).

Interaction effect of variety and micronutrient

RGR was significantly influenced due to interaction of variety and micronutrient in every successive growth stages of wheat in both the cropping seasons. BARI Gom 28 (V_2) gave the maximum RGR with the application of combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) at CRI- Tillering stage and Tillering- Booting stage in both the years. BARI Gom 26 (V_1) produced statistically more or less similar results with combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in 2nd year (Figure 24, Figure 25 and Appendix XXV).

Interaction effect of sowing time, variety and micronutrient

Relative growth rate (RGR) of wheat showed statistically significant variation due to different interaction effect of sowing time, variety and micronutrient at all sampling stages in both seasons. From the result in 1st year BARI Gom 26 (V_1) produce highest RGR with combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in 25^{th} November (D_1) on the contrary in 2nd year BARI Gom 28 (V_2) produce highest RGR with combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in 25^{th} November (D_1) at tillering to booting stage. No clear pattern of treatment effect on relative growth rate (RGR) was observed in both the years (Table 4a and Table 4b).

Table 4a. Interaction effect of late seeding, variety and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 1st year

Parameter / Interaction	1st year RGR (g g^{-1} day^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	0.11a	0.104abc	0.074ab	0.029a	0.008a
$D_1V_1M_1$	0.108a	0.122abc	0.064ab	0.029a	0.007a
$D_1V_1M_2$	0.112a	0.138ab	0.056b	0.028a	0.006a
$D_1V_1M_3$	0.113a	**0.146a**	0.053b	0.027a	0.005a
$D_1V_2M_0$	0.109a	0.111abc	0.07ab	0.027a	0.007a
$D_1V_2M_1$	0.109a	0.127abc	0.061ab	0.028a	0.007a
$D_1V_2M_2$	0.112a	0.139ab	0.056b	0.028a	0.006a
$D_1V_2M_3$	0.114a	0.147a	0.053b	0.028a	0.005a
$D_2V_1M_0$	0.113a	0.062abc	0.129ab	**0.049a**	0.009a
$D_2V_1M_1$	0.108a	0.09abc	0.095ab	0.043a	0.009a
$D_2V_1M_2$	0.11a	0.102abc	0.084ab	0.041a	0.008a
$D_2V_1M_3$	0.114a	0.109abc	0.078ab	0.043a	0.007a
$D_2V_2M_0$	0.111a	0.072abc	0.12ab	0.043a	0.008a
$D_2V_2M_1$	0.108a	0.091abc	0.097ab	0.04a	0.009a
$D_2V_2M_2$	0.111a	0.103abc	0.086ab	0.039a	0.007a
$D_2V_2M_3$	0.114a	0.11abc	0.08ab	0.04a	0.006a
$D_3V_1M_0$	**0.171a**	0.051c	**0.141a**	0.048a	**0.01a**
$D_3V_1M_1$	0.163a	0.083abc	0.105ab	0.038a	0.009a
$D_3V_1M_2$	0.165a	0.098abc	0.089ab	0.042a	0.008a
$D_3V_1M_3$	0.169a	0.105abc	0.083ab	0.042a	0.007a
$D_3V_2M_0$	0.169a	0.057bc	0.136ab	0.047a	0.01a
$D_3V_2M_1$	0.162a	0.086abc	0.101ab	0.04a	0.009a
$D_3V_2M_2$	0.165a	0.098abc	0.091ab	0.04a	0.008a
$D_3V_2M_3$	0.17a	0.109abc	0.077ab	0.041a	0.007a
LS	0.010	0.010	0.010	0.010	0.010
CV	0.86	2.72	2.10	5.32	9.45

Table 4b. Interaction effect of late seeding, variety and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2nd year

Parameter / Interaction	2nd year RGR (g g^{-1} day^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	0.107a	0.094a-d	0.074a	0.035a	0.01a
$D_1V_1M_1$	0.109a	0.122a-d	0.056a	0.033a	0.008a
$D_1V_1M_2$	0.111a	0.138abc	0.053a	0.03a	0.006a
$D_1V_1M_3$	0.114a	0.145ab	0.049a	0.032a	0.005a
$D_1V_2M_0$	0.107a	0.101a-d	0.069a	0.036a	0.009a
$D_1V_2M_1$	0.108a	0.126a-d	0.056a	0.033a	0.008a
$D_1V_2M_2$	0.112a	0.14abc	0.05a	0.032a	0.006a
$D_1V_2M_3$	0.113a	**0.146a**	0.049a	0.033a	0.005a
$D_2V_1M_0$	0.113a	0.061bcd	0.116a	**0.06a**	0.012a
$D_2V_1M_1$	0.109a	0.085a-d	0.089a	0.055a	0.01a
$D_2V_1M_2$	0.11a	0.099a-d	0.078a	0.051a	0.008a
$D_2V_1M_3$	0.113a	0.109a-d	0.07a	0.048a	0.007a
$D_2V_2M_0$	0.109a	0.068a-d	0.109a	0.056a	0.012a
$D_2V_2M_1$	0.11a	0.087a-d	0.093a	0.051a	0.01a
$D_2V_2M_2$	0.111a	0.103a-d	0.079a	0.046a	0.008a
$D_2V_2M_3$	0.114a	0.109a-d	0.074a	0.046a	0.007a
$D_3V_1M_0$	**0.174a**	0.05d	**0.123a**	0.062a	**0.013a**
$D_3V_1M_1$	0.164a	0.079a-d	0.096a	0.053a	0.011a
$D_3V_1M_2$	0.164a	0.095a-d	0.085a	0.048a	0.008a
$D_3V_1M_3$	0.168a	0.105a-d	0.075a	0.047a	0.007a
$D_3V_2M_0$	0.171a	0.059cd	0.115a	**0.06a**	0.013a
$D_3V_2M_1$	0.164a	0.081a-d	0.095a	0.056a	0.011a
$D_3V_2M_2$	0.165a	0.097a-d	0.082a	0.051a	0.009a
$D_3V_2M_3$	0.169a	0.106a-d	0.075a	0.049a	0.008a
LS	0.010	0.010	0.010	0.010	0.010
CV	2.43	2.25	2.94	6.32	10.5

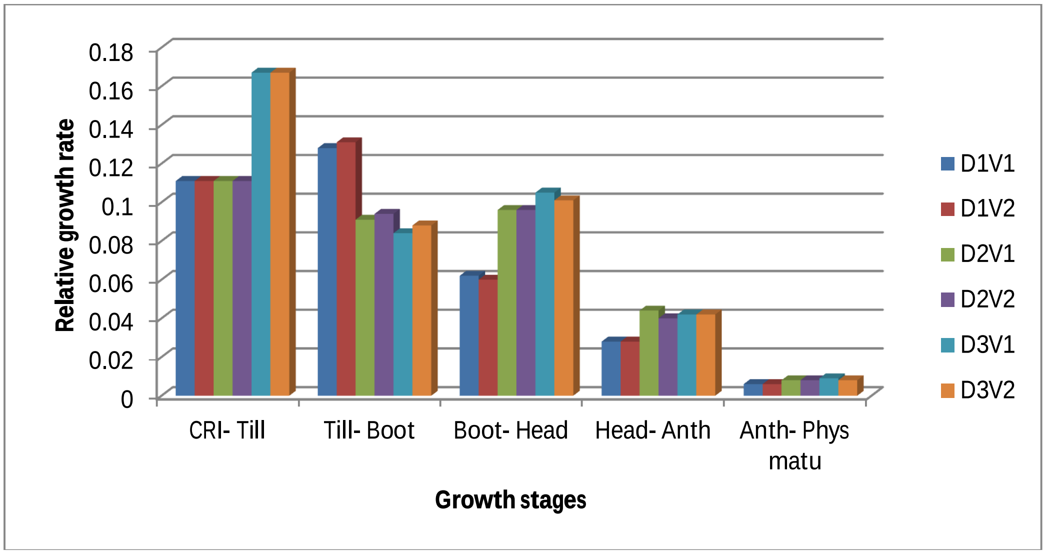


Figure 20: Interaction effect of late seeding and variety on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2015 - 2016

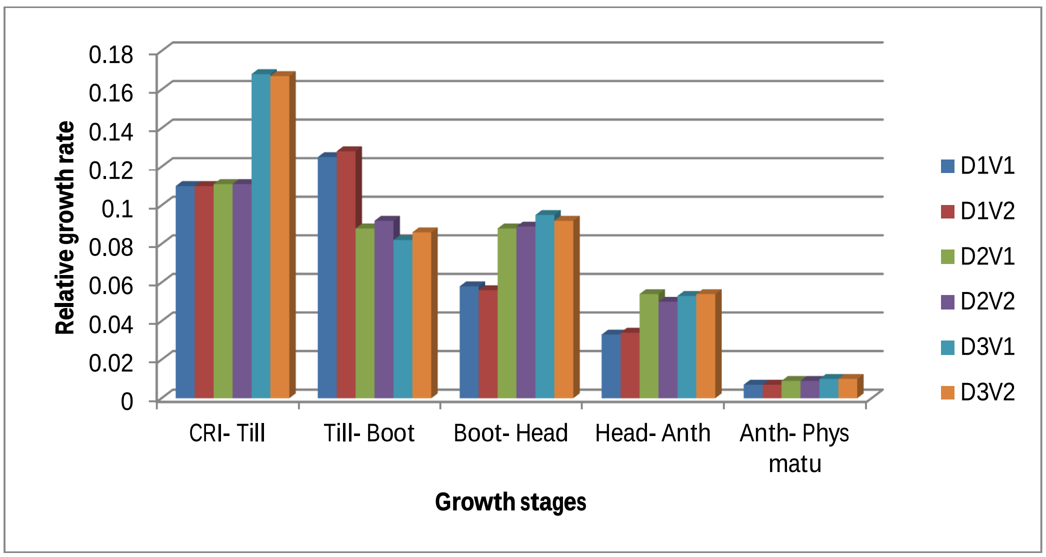


Figure 21: Interaction effect of late seeding and variety on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2017 - 2018

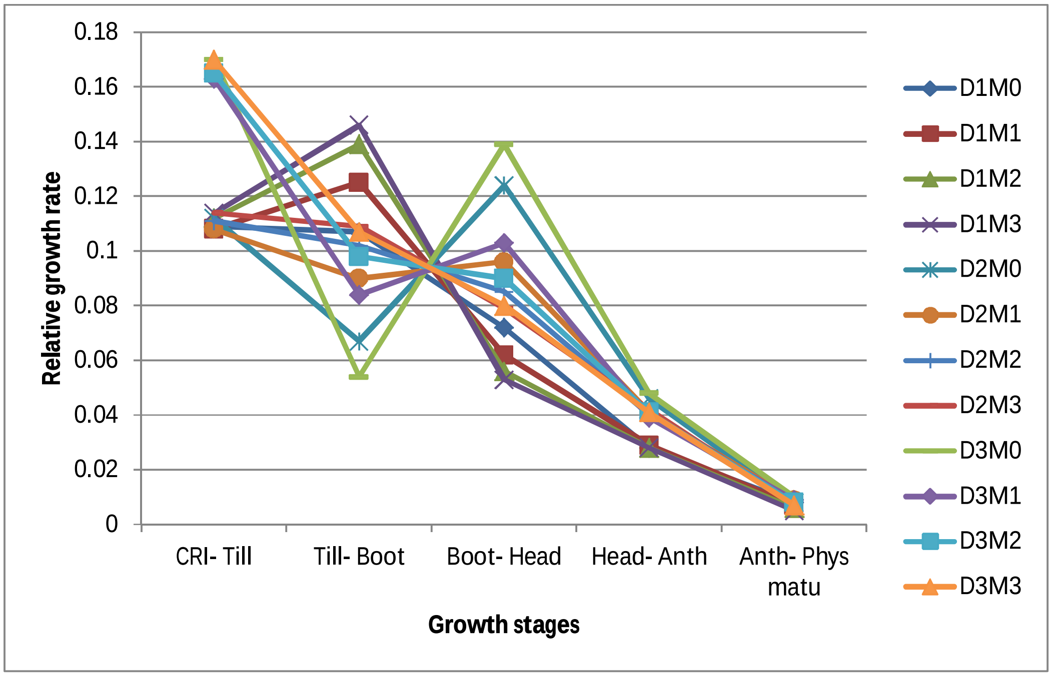


Figure 22: Interaction effect of late seeding and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2015 - 2016

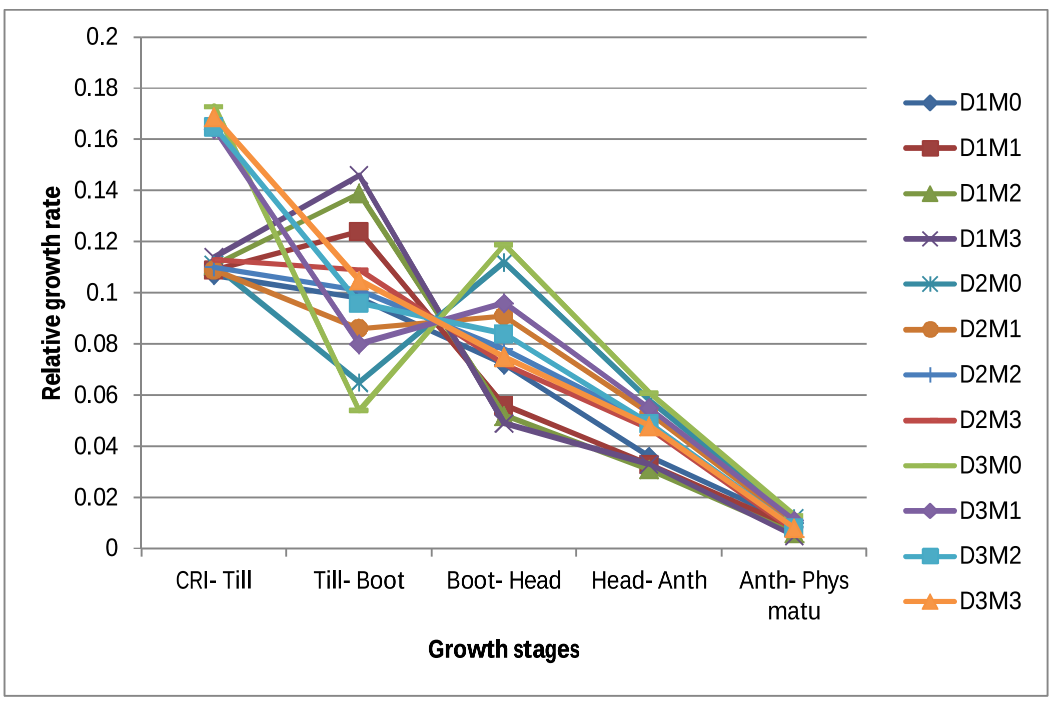


Figure 23: Interaction effect of late seeding and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2017 - 2018

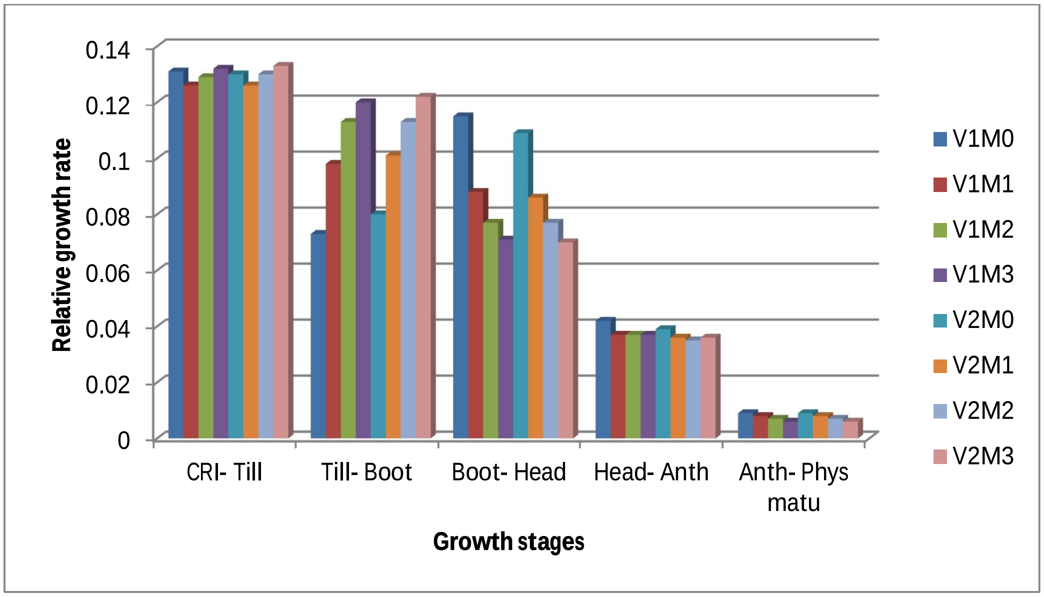


Figure 24: Interaction effect of variety and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2015 - 2016

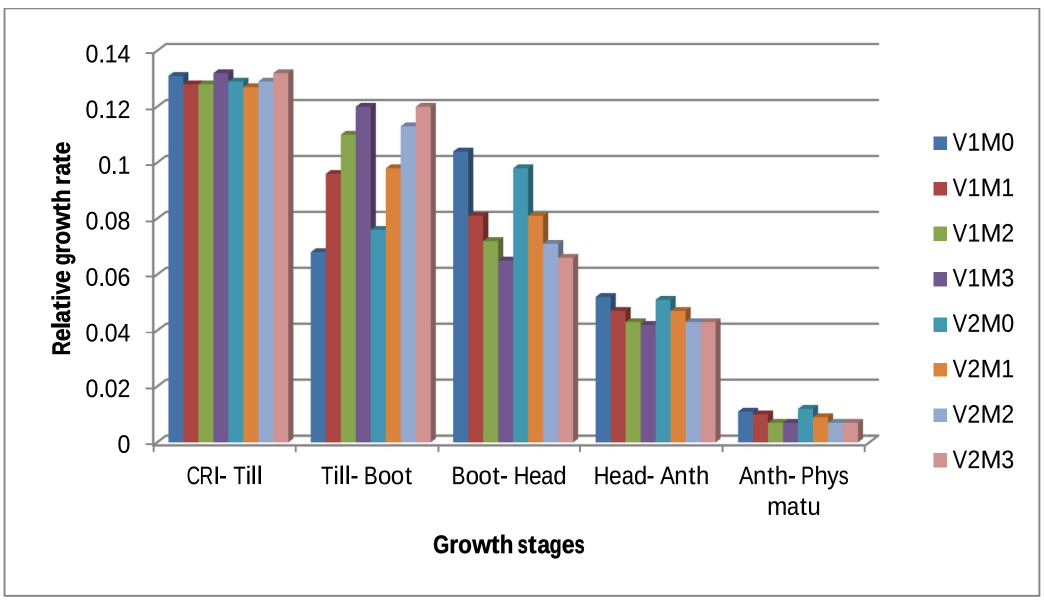


Figure 25: Interaction effect of variety and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat in 2017 - 2018

4.1.5 Net Assimilation Rate (NAR)

Effect of sowing time

Net assimilation rate varied significantly due to sowing date at all the growth stages in both the cropping seasons. NAR increase from CRI to tillering stage then get peak value at Booting to heading stage in both the years. After getting peak value net assimilation rate decreased with the increasing growth period. At tillering to booting stage the highest net assimilation rate was obtained in plants sown in 25th November (D_1) and lowest value in 25th December (D_3) in both experimental years.

Effect of variety

Variety significantly influenced net assimilation rate at all the sampling stages in both the growing seasons. The pattern of development of net assimilation rate values in 1st year was found to be more or less similar net assimilation rate as that of 2nd year. Significantly the highest net assimilation rate was observed in the variety BARI Gom 26 (V_1) at CRI to tillering stage, heading to anthesis stage and anthesis to physiological maturity stage in 1st year. The second year the highest net assimilation rate was observed in BARI Gom 28 (V_2) at all the growth stages except CRI to tillering stage.

Effect of micronutrient

Net assimilation rate differed significantly due to micronutrients level at all the sampling period in both the seasons. The highest net assimilation rate was observed at tillering to booting stage, booting to heading stages and heading to anthesis stage with the application of combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) except CRI to tillering stage and anthesis to physiological maturity stage in both the seasons and the lowest one from the control (M_0) treatment at tillering to booting stage in 1st year and tillering to booting stage and heading to anthesis stage in 2nd year.

Interaction effect of sowing time and variety

Net assimilation rate varied significantly due to the interaction of sowing date and variety at all the successive growth stages in both the experimental years except CRI to tillering stage and tillering to booting stage. Significantly the highest net assimilation rate was obtained by the treatment combination of D_1V_2 and the lowest net assimilation rate was observed in D_3V_1 in both the growing seasons within the period of tillering to booting stage (Figure 26, Figure 27 and Appendix XXVI).

Interaction effect of sowing time and micronutrient

The interaction effect between sowing date and micronutrients level on net assimilation rate was statistically significant at all the successive growth stages in both the seasons except anthesis to physiological maturity stage in the 1st year. The maximum net assimilation rate was observed in D_1M_3 and the lowest in D_3M_0 during the period of tillering to booting stage in both years (Figure 28, Figure 29 and Appendix XXVII).

Interaction effect of variety and micronutrient

The effect of interaction between variety and micronutrient treatments was significant at all the stages in both the years except tillering to booting stage in 1st year (Figure 30, Figure 31 and Appendix XXVIII). In all the treatments and both the cultivars NAR values showed fluctuation heavily throughout the growing period. On the other hand, NAR increased progressively from CRI to tillering stage up to booting to heading stage and then decreased at heading to anthesis stage in both the cultivars.

Interaction effect of sowing time, variety and micronutrient

The interaction effect between sowing time, variety and micronutrient level on net assimilation rate was statistically significant at all the successive growth stages in both the seasons except tillering to booting stage in the both years. The maximum net assimilation rate was observed in $D_1V_2M_3$ and the lowest in $D_3V_1M_0$ during the period of tillering to booting stage in both years (Table 5a and Table 5b).

Table 5a. Interaction effect of late seeding, variety and micronutrient on net assimilation rate (mg cm^{-2} day^{-1})at different growth stages of wheat in 1st year

Parameter / Interaction	1st year NAR ($mgcm^{-2}day^{-1}$)				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	0.438c	0.713	1.272d	0.791jk	0.28abc
$D_1V_1M_1$	0.4c	0.9	1.178d	0.85ijk	0.27abc
$D_1V_1M_2$	0.406c	1.203	1.258d	0.898ijk	0.247bc
$D_1V_1M_3$	0.414c	1.409	1.305d	0.956hij	0.247bc
$D_1V_2M_0$	0.418c	0.78	1.253d	0.744k	0.275abc
$D_1V_2M_1$	0.404c	0.994	1.183d	0.838ijk	0.272abc
$D_1V_2M_2$	0.41c	1.234	1.262d	0.916ijk	0.248bc
$D_1V_2M_3$	0.419c	**1.413**	1.332d	0.965g-j	0.243c
$D_2V_1M_0$	0.462c	0.366	1.881abc	1.245b-e	0.307abc
$D_2V_1M_1$	0.402c	0.646	1.667c	1.187cde	0.327ab
$D_2V_1M_2$	0.407c	0.879	1.801abc	1.299a-d	0.33ab
$D_2V_1M_3$	0.413c	1.046	1.879abc	1.45a	0.306abc
$D_2V_2M_0$	0.447c	0.471	**1.994a**	1.159def	0.311abc
$D_2V_2M_1$	0.403c	0.677	1.799abc	1.127d-h	0.325abc
$D_2V_2M_2$	0.411c	0.893	1.903abc	1.241b-e	0.314abc
$D_2V_2M_3$	0.415c	1.055	1.971ab	**1.399ab**	0.291abc
$D_3V_1M_0$	**0.758a**	0.278	1.817abc	1.131d-g	**0.347a**
$D_3V_1M_1$	0.635b	0.572	1.798abc	1.006f-i	0.322abc
$D_3V_1M_2$	0.611b	0.794	1.804abc	1.28a-d	0.35a
$D_3V_1M_3$	0.615b	0.94	1.906abc	1.377ab	0.321abc
$D_3V_2M_0$	0.722a	0.325	1.889abc	1.154def	0.345a
$D_3V_2M_1$	0.622b	0.607	1.717bc	1.098e-h	0.345a
$D_3V_2M_2$	0.611b	0.805	1.881abc	1.26b-e	0.326abc
$D_3V_2M_3$	0.624b	1.029	1.838abc	1.352abc	0.318abc
LS	0.010	NS	0.010	0.010	0.010
CV	1.96	4.28	6.25	6.50	7.71

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Table 5b. Interaction effect of late seeding, variety and micronutrient on net assimilation rate (mg cm^{-2} day^{-1})at different growth stages of wheat in 2nd year

Parameter / Interaction	2nd year NAR (mg$cm^{-2}$$day^{-1}$)				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	0.417c	0.584	1.088f	0.871g	0.356b-f
$D_1V_1M_1$	0.409c	0.923	0.995f	0.9g	0.292f-j
$D_1V_1M_2$	0.412c	1.209	1.135f	0.947fg	0.266hij
$D_1V_1M_3$	0.415c	1.39	1.172f	1.101f	0.237j
$D_1V_2M_0$	0.406c	0.637	1.055f	0.934fg	0.349c-g
$D_1V_2M_1$	0.407c	0.987	1.03f	0.951fg	0.3f-j
$D_1V_2M_2$	0.41c	1.253	1.102f	1.024fg	0.27g-j
$D_1V_2M_3$	0.418c	**1.415**	1.182f	1.118f	0.242ij
$D_2V_1M_0$	0.454c	0.359	1.566b-e	1.407b-e	0.416abc
$D_2V_1M_1$	0.417c	0.59	1.397e	1.4b-e	0.364b-f
$D_2V_1M_2$	0.406c	0.812	1.517b-e	1.523a-d	0.33d-h
$D_2V_1M_3$	0.418c	1.046	1.624a-d	1.58ab	0.319e-i
$D_2V_2M_0$	0.431c	0.42	1.55b-e	1.351de	0.43ab
$D_2V_2M_1$	0.408c	0.616	1.573b-e	1.364de	0.368b-f
$D_2V_2M_2$	0.408c	0.897	1.696ab	1.462a-e	0.336c-h
$D_2V_2M_3$	0.418c	1.05	**1.793a**	1.57abc	0.322e-h
$D_3V_1M_0$	**0.763a**	0.279	1.489b-e	1.315e	0.405a-d
$D_3V_1M_1$	0.624b	0.52	1.461cde	1.318e	0.386a-e
$D_3V_1M_2$	0.615b	0.753	1.605a-e	1.402b-e	0.355b-f
$D_3V_1M_3$	0.622b	0.954	1.666abc	1.507a-e	0.328d-h
$D_3V_2M_0$	0.719a	0.347	1.5b-e	1.371cde	**0.455a**
$D_3V_2M_1$	0.624b	0.538	1.439de	1.405b-e	0.391a-e
$D_3V_2M_2$	0.611b	0.779	1.595a-e	1.496a-e	0.352b-f
$D_3V_2M_3$	0.625b	0.968	1.678ab	**1.603a**	0.345c-h
LS	0.010	NS	0.010	0.010	0.010
CV	3.16	3.19	5.93	5.77	9.48

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. NS = Not significant

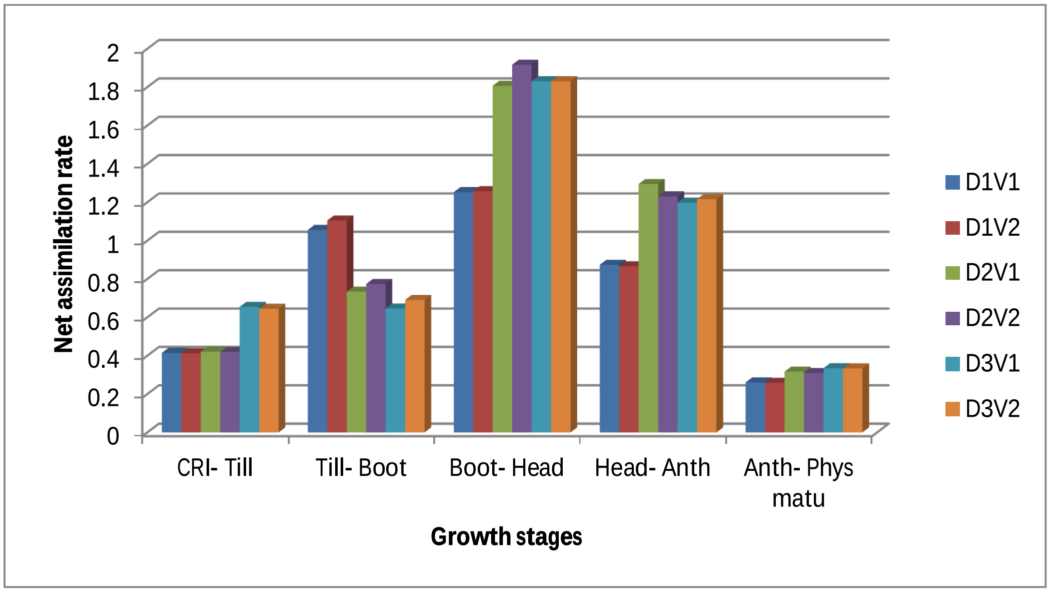


Figure 26: Interaction effect of late seeding and variety on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

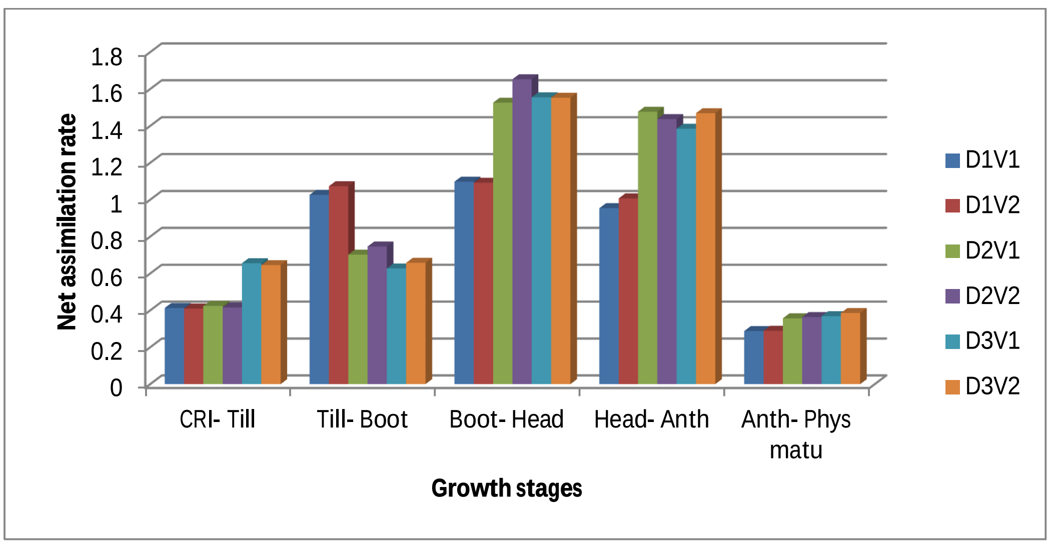


Figure 27: Interaction effect of late seeding and variety on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

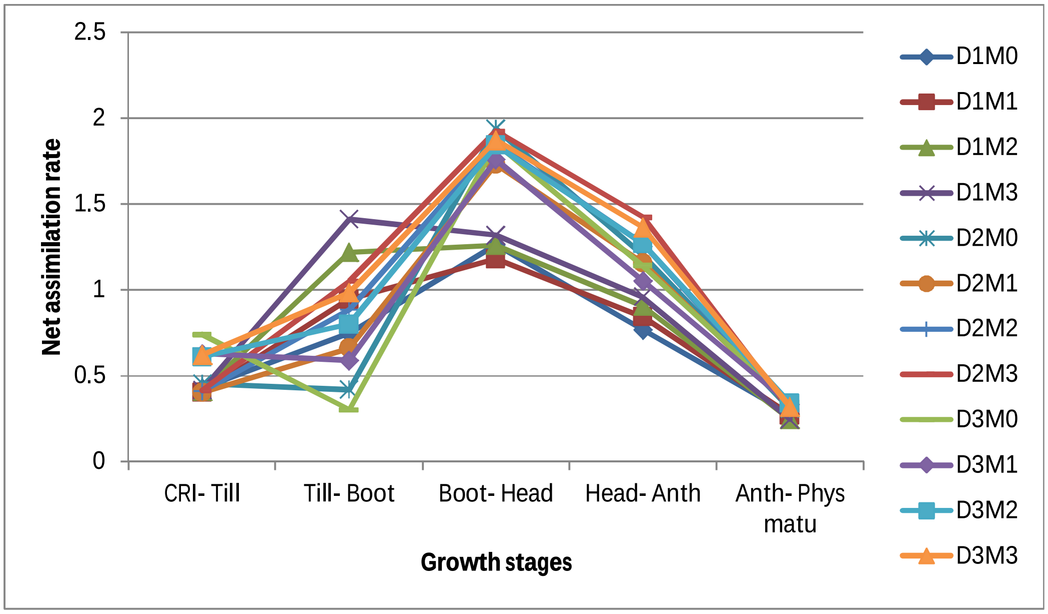


Figure 28: Interaction effect of late seeding and micronutrient on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

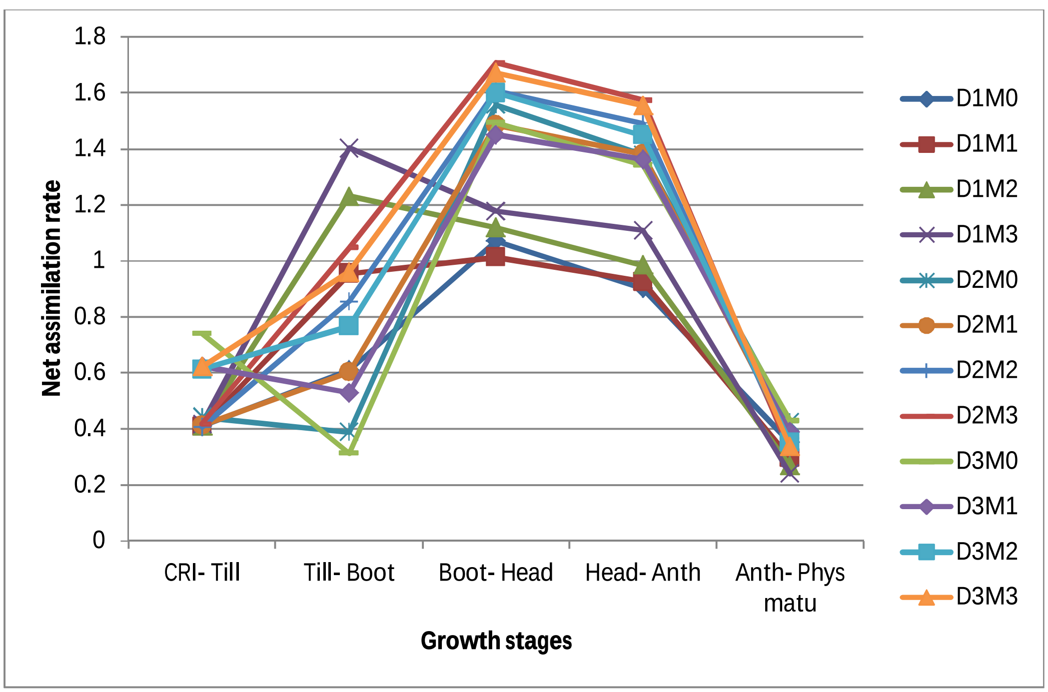


Figure 29: Interaction effect of late seeding and micronutrient on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

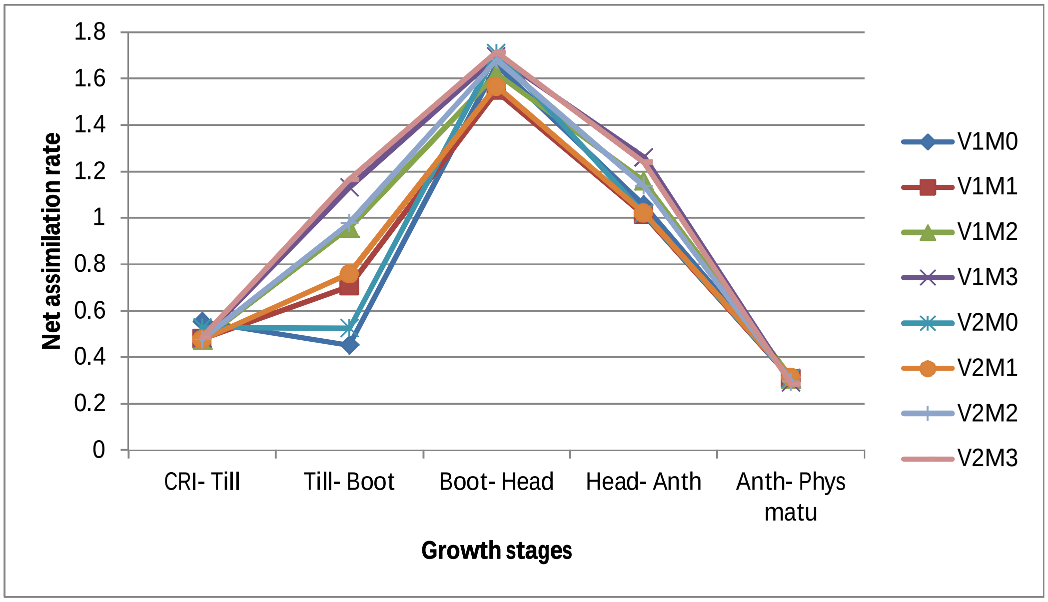


Figure 30: Interaction effect of variety and micronutrient on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2015 - 2016

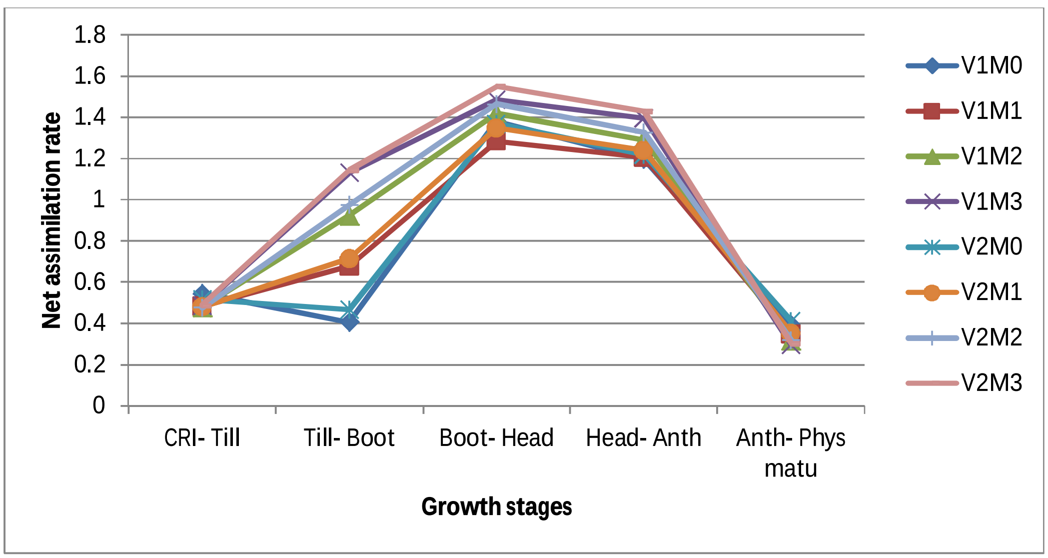


Figure 31: Interaction effect of variety and micronutrient on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in 2017 - 2018

4.1.6 Leaf Area Ratio (LAR)

Effect of sowing time

Leaf area ratio varied significantly due to sowing date at all the harvest in both the cropping seasons. The highest leaf area ratio was found in 25th November (D_1) at crown root initiation to tillering stages followed by 10th December (D_2) and 25th December (D_3) in both the years. Leaf area ratio value decreased with increasing growth period. The lowest leaf area ratio was recorded at anthesis to physiological maturity stage in both the years.

Effect of variety

The effect of variety on leaf area ratio for both the experiments is shown in. Leaf area ratio varied significantly due to varieties in all the growth stages in both the years. Leaf area ratio values under different varieties were found high at early stages then declined with increasing growth period. The maximum leaf area ratio was recorded from BARI Gom 26 (V_1) at most of the growth stages except crown root initiation to tillering stages in both the experimental years.

Effect of micronutrient

Micronutrient level showed significant effect on leaf area ratio in all the growth stages in both the years. At crown root initiation to tillering stages the highest leaf area ratio was noted at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the experimental years followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) compared to control treatment.

Interaction effect of sowing time and variety

Leaf area ratio was significantly influenced by the interaction of sowing time and variety at all the successive growth stages in both the seasons except CRI to tillering stage and heading to anthesis stage in 1st year and booting to heading stage in 2nd year. Clear pattern was not observed of treatment effect on leaf area ratio (LAR) in both the experimental years. Leaf area ratio value declined in the successive growth stage and it reached the lowest at anthesis to physiological maturity stage (Figure 32, Figure 33 and Appendix XXIX).

Interaction effect of sowing time and micronutrient

Sowing time and micronutrient level interaction showed significant effect in leaf area ratio at all the successive growth stages in both the years except heading to anthesis stage and anthesis to physiological maturity stage in 1st year and booting to heading stage, heading to anthesis stage and anthesis to physiological maturity stage in 2nd year. The highest leaf area ratio was recorded in 25^{th} November (D_1) with Zinc (5.30 kg ha^{-1}) (M_2) treatment in 1st year and 25^{th} November (D_1) with combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in 2nd year at CRI- Tillering stage (Figure 34, Figure 35 and Appendix XXX).

Interaction effect of variety and micronutrient

The effect of interaction between the variety and micronutrient treatment was significant at CRI to tillering stage, heading to anthesis stage and anthesis to physiological maturity stage in 1st year and CRI to tillering stage, booting to heading stage and heading to anthesis stage in 2nd year (Figure 36, Figure 37 and Appendix XXXI). At CRI to tillering stage Influence of variety and micronutrient treatment on leaf area ratio (LAR) of wheat cultivars gets highest value at V_1M_3 treatment combination is presented in Figure 36 and Figure 37 for the two years. In all the treatments of both the cultivars and years LAR values showed maximum at the first growth stage (CRI to tillering stage) and gradually decreased with the age of the plant.

Interaction effect of sowing time, variety and micronutrient

Sowing time, variety and micronutrient level interaction showed significant effect in leaf area ratio at all the successive growth stages in both the years except CRI to tillering stage in 2nd year. Treatment combination $D_3V_1M_0$ gave the highest value in most of the growth stages except CRI to tillering stage both the years. Clear pattern was not observed of treatment effect on leaf area ratio (LAR) in both the experimental years (Table 6a and Table 6b).

Table 6a. Interaction effect of late seeding, variety and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 1st year

Parameter / Interaction	1st year LAR (cm^2 g^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	250.989efg	146.657cd	58.629c	36.379cde	27.374a-d
$D_1V_1M_1$	269.786abc	135.374def	54.661cde	34.577d-h	25.135def
$D_1V_1M_2$	**275.394a**	114.822hij	44.984ghi	30.832hij	22.998fg
$D_1V_1M_3$	274.034a	104.157j	40.519hi	28.747j	21.564g
$D_1V_2M_0$	259.661cde	142.896cd	56.589cd	35.915c-f	27.07bcd
$D_1V_2M_1$	269.111abc	127.823e-h	51.451c-g	33.654d-i	24.734def
$D_1V_2M_2$	274.561a	112.786ij	44.143ghi	30.436hij	22.705fg
$D_1V_2M_3$	271.834a	103.63j	40.095i	28.556j	21.446g
$D_2V_1M_0$	243.359gh	170.433b	68.775b	39.339abc	28.5abc
$D_2V_1M_1$	268.861abc	138.718de	57.107cd	36.5b-e	26.528bcd
$D_2V_1M_2$	271.472a	116.428hij	46.857e-i	31.853f-j	23.523efg
$D_2V_1M_3$	275.209a	104.826j	41.314hi	29.229j	21.733g
$D_2V_2M_0$	248.255fg	153.505c	60.371c	36.761b-e	28.069abc
$D_2V_2M_1$	267.638abc	134.696d-g	54.149c-f	35.174c-g	26.111cde
$D_2V_2M_2$	270.616ab	114.901hij	45.375f-i	31.263g-j	23.546efg
$D_2V_2M_3$	273.648a	104.109j	40.381hi	28.717j	21.684g
$D_3V_1M_0$	226.261i	**186.315a**	**77.814a**	**42.643a**	**29.787a**
$D_3V_1M_1$	256.679def	144.371cd	58.646c	37.645bcd	28.452abc
$D_3V_1M_2$	269.587abc	123.225f-i	49.428d-h	32.616e-j	23.902efg
$D_3V_1M_3$	275.055a	111.959ij	43.833ghi	30.234ij	22.434fg
$D_3V_2M_0$	234.751hi	177.335ab	72.655ab	40.656ab	29.066ab
$D_3V_2M_1$	260.749bcd	142.205cd	58.505c	37.017bcd	27.074bcd
$D_3V_2M_2$	270.31ab	122.128ghi	48.297d-i	32.098f-j	23.868efg
$D_3V_2M_3$	272.262a	105.626j	42.01hi	30.071ij	22.42fg
LS	0.010	0.010	0.010	0.010	0.010
CV	1.54	4.14	6.88	5.05	4.33

Table 6b. Interaction effect of late seeding, variety and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2nd year

Parameter / Interaction	2nd year LAR (cm^2 g^{-1})				
	CRI- Tillering Stage	**Tillering- Booting Stage**	**Booting- Heading Stage**	**Heading- Anthesis Stage**	**Anthesis- Physiological maturity Stage**
$D_1V_1M_0$	256.991	163.496bc	68.339b-e	40.38bcd	27.993bc
$D_1V_1M_1$	267.678	132.525gh	56.797fg	36.792def	25.689de
$D_1V_1M_2$	269.408	113.944jkl	46.422hij	31.942ghi	23.137g-j
$D_1V_1M_3$	**273.747**	104.699l	41.856j	29.402i	21.334jk
$D_1V_2M_0$	265.017	159.032cd	66.111cde	39.009cde	26.638cd
$D_1V_2M_1$	266.648	127.821hi	53.931gh	35.18efg	24.511efg
$D_1V_2M_2$	272.046	111.784kl	45.584hij	31.358ghi	22.465h-k
$D_1V_2M_3$	271.904	103.309l	41.198j	29.209i	21.117k
$D_2V_1M_0$	249.271	171.366ab	73.902bc	42.712bc	28.796b
$D_2V_1M_1$	262.441	144.037ef	63.904def	39.337cd	26.554cd
$D_2V_1M_2$	271.239	121.572ijk	51.285ghi	33.914fgh	23.75f-i
$D_2V_1M_3$	271.945	104.286l	42.958ij	30.567hi	21.919ijk
$D_2V_2M_0$	253.015	163.897bc	70.248bcd	41.652bc	28.148bc
$D_2V_2M_1$	269.205	141.001fg	59.416efg	37.034def	25.502def
$D_2V_2M_2$	271.11	114.651jkl	46.702hij	31.816ghi	22.741g-k
$D_2V_2M_3$	272.396	103.935l	41.519j	29.49i	21.39jk
$D_3V_1M_0$	228.129	**178.939a**	**83.408a**	**47.231a**	**30.88a**
$D_3V_1M_1$	263.915	152.664de	66.234cde	40.81bcd	27.735bc
$D_3V_1M_2$	267.097	126.158hi	53.032gh	34.597fgh	24.271e-h
$D_3V_1M_3$	271.047	110.359l	45.303hij	31.505ghi	22.504h-k
$D_3V_2M_0$	238.072	170.289ab	76.397ab	44.203ab	28.919b
$D_3V_2M_1$	262.408	150.608def	66.014cde	39.663cd	26.514cd
$D_3V_2M_2$	269.491	124.242hij	51.748ghi	33.845fgh	23.602ghi
$D_3V_2M_3$	270.438	109.24l	44.685hij	30.847hi	21.848ijk
LS	NS	0.010	0.010	0.010	0.010
CV	1.17	3.36	6.61	4.66	3.10

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

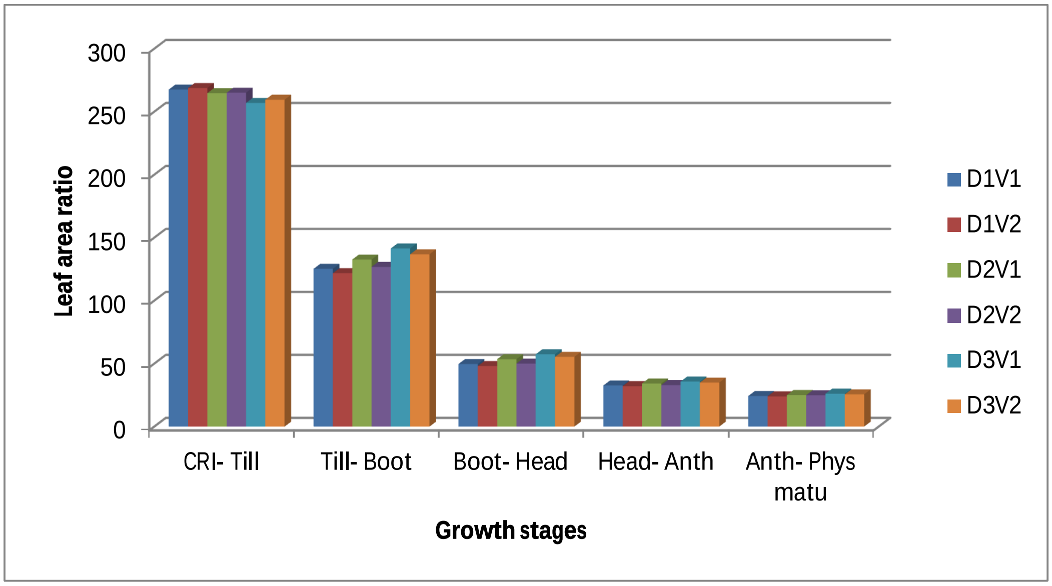


Figure 32: Interaction effect of late seeding and variety on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2015 - 2016

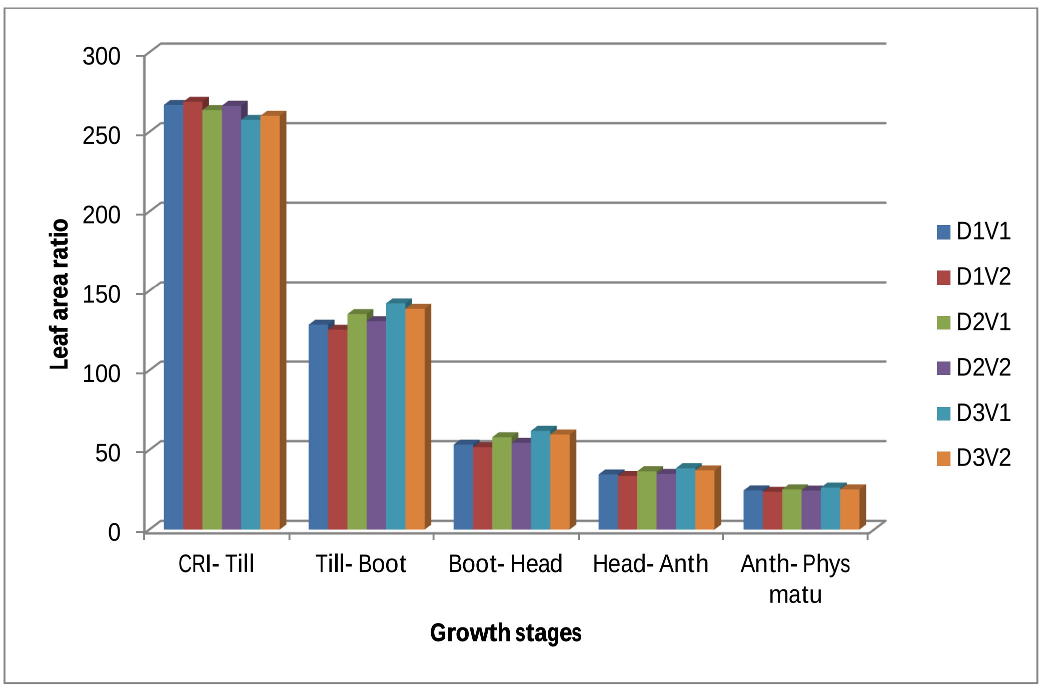


Figure 33: Interaction effect of late seeding and variety on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2017 - 2018

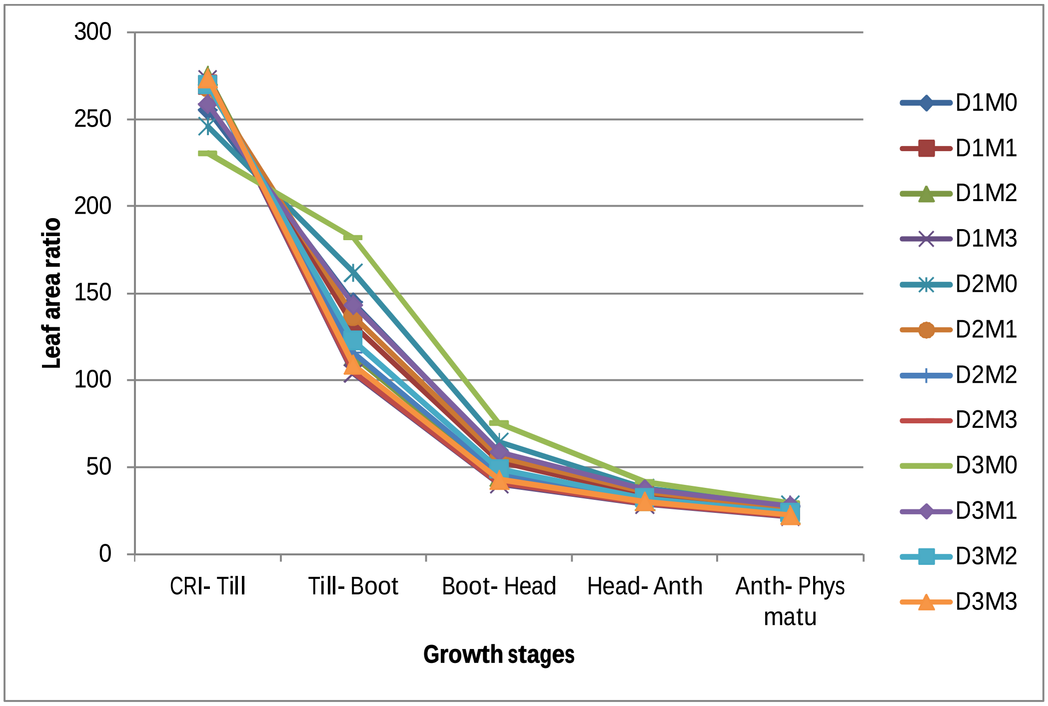


Figure 34: Interaction effect of late seeding and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2015 - 2016

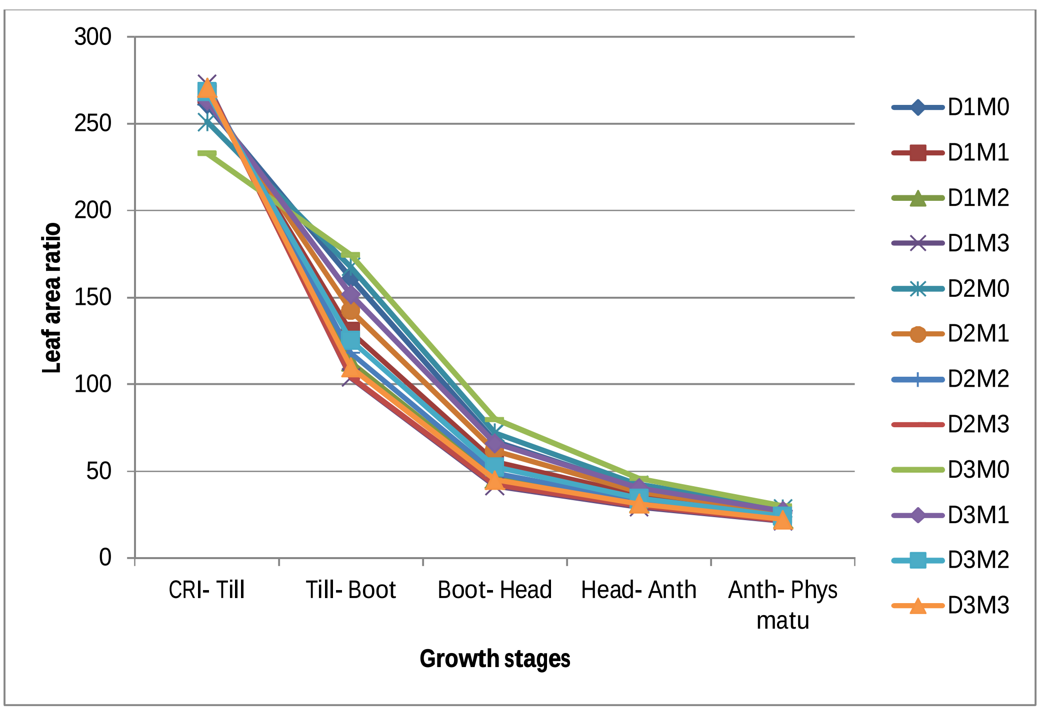


Figure 35: Interaction effect of late seeding and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2017 - 2018

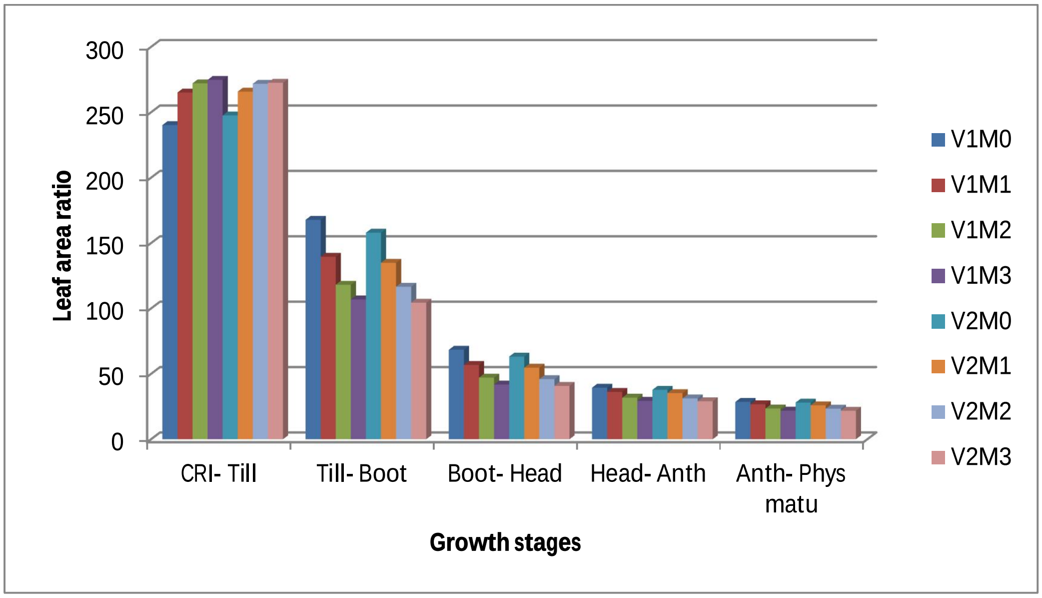


Figure 36: Interaction effect of variety and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2015 - 2016

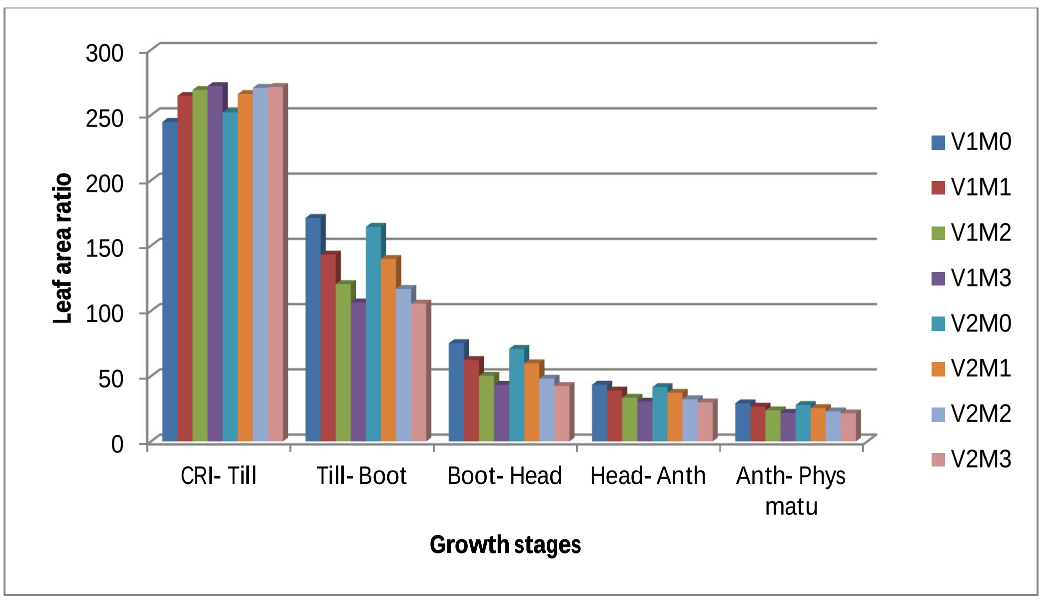


Figure 37: Interaction effect of variety and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat in 2017 - 2018

4.2 Yield and yield contributing characters

In 1st year, results showed that all yield and yield contributing characters were significantly influenced due to sowing date. All yield and yield contributing characters studied were significant due to variety except plant height and biological yield, all yield and yield components varied significantly due to micronutrient levels. Kenbaev and Sade (2002) and Hosseini (2006) have reported increase in yield components for foliar application of zinc.

All yield and yield contributing characters except spikelets spike^{-1} and grains Spike^{-1} varied significantly due to the interaction of sowing date and variety.

All yield and contributing characters differed significantly due to interaction of sowing date and micronutrient.

Among the yield and yield contributing characters plant height, total tillers plant^{-1}, effective tilles plant^{-1}, spikelets spike^{-1}, spike length, grain spike^{-1}1000 grain weight, biological yield and grain yield varied significantly due to the interaction of variety and micronutrient levels.

On the other hand, in 2nd year, results showed that all yield and yield contributing characters were significantly influenced due to sowing date. All yield and yield contributing characters studied were significant due to variety except plant height, spike length and biological yield, all yield and yield components varied significantly due to micronutrient levels.

All yield and yield contributing characters except grains spike^{-1} varied significantly due to the interaction of sowing date and variety.

All yield and yield contributing characters differed significantly due to interaction of sowing date and micronutrient except grain yield.

Among the yield and yield contributing characters plant height, total tillers plant^{-1}, effective tilles plant^{-1}, spikelets spike^{-1}, spike length, grain spike^{-1}, 1000 grain weight, biological yield and grain yield varied significantly due to the interaction of variety and micronutrient levels.

4.2.1 Plant height

Plant height varied significantly due late seeding in both the experimental years. The tallest plant (92.085 cm and 89.648 cm) were resulted 25th November (D_1) in 1st and 2nd year and the lowest plant height (88.936 cm and 86.408 cm) were found in 25th December (D_3) in 1st and 2nd year.

There was insignificant effect in respect of plant height due to by varieties in both the years. BARI Gom 26 (V_1) had the tallest plant (90.551cm and 88.162cm). The shortest plant was obtained from the variety BARI Gom 28 (V_2) (90.459cm and 87.977cm) in 1st and 2nd year respectively.

Under the present study, micro-nutrients levels responded significantly due to plant height in both the years. Heat stress caused a significant decrease in plant height. On the other hand, micro-nutrients application resulted in a significant increase in plant height. Results revealed that the tallest plant (98.778a cm and 96.368a cm) was achieved from combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest values (79.135 cm and 76.954 cm) was observed in control (M_0) in both the years. BINA, (1993) reported that plant height varied significantly by application of 1 kg ha^{-1}.

Here, it was also observed that micro-nutrients had a contribution for higher plant growth when the crop field was treated with combination of (B 1.25 kg ha^{-1} +Zn 5.30 kg ha^{-1}) (M_3) treatment where no application of micro-nutrients treatment showed shortest plant height.

It is noticed that plant height varied significantly due to the interaction of late seeding and variety in both the trials. The highest plant height (92.441 cm and 89.931 cm) was found in D_1V_2 treatment combination and the lowest plant height (88.501 cm and 85.929 cm) was observed in D_3V_2 treatment combination in both the years respectively (Table 7a and 7b).

The interaction of late seeding and micronutrient had significant effect on plant height in both the years. The tallest plant (100.175 cm and 97.972 cm) was found in D_1M_3 treatment combination and the lowest plant height (77.021 cm and 75.025cm) was recorded in D_3M_0 treatment combination in 1st and 2nd year respectively (Table 9a and 9b).

Significant effect was observed on plant height due to the interaction between variety and micronutrient in both the trials. Significantly the highest plant height (99.06 cm and 96.4 cm) was recorded in V_2M_3 treatment combination and the lowest plant height (78.902 cm and 76.791 cm) was found in V_2M_0 treatment combination in 1st and 2nd year respectively (Table 10a and 10b).

4.2.2 Number of total tillers plant^{-1}

The number of total tillers plant^{-1} varied significantly due to late seeding in both the years. An increasing trend on production of number of total tillers plant^{-1} was noticed in late seeding. In 1st year, the highest number of total tillers plant^{-1} (5.320) was found in 25th December (D_3) and the lowest (4.927) in 25th November (D_1). In 2nd year, the highest number of total tillers plant^{-1} was observed in 25th December (D_3). The lowest number of total tillers plant^{-1} (5.020) was recorded in 25th November (D_1).

The number of total tillers plant^{-1} was significantly influenced by variety in both the years. The highest number of total tillers plant^{-1} was obtained in BARI Gom26 (V_1) and the lowest was in BARI Gom28 (V_2) in both the years.

Micro-nutrients levels had significant effect in respect of number of total tillers plant^{-1} in both the trials. The highest number of total tillers plant^{-1} was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. The lowest number of total tillers plant^{-1} was found in control (M_0) in both the years (Table 8a and 8b).

The interaction effect of late seeding and variety was significant for number of total tillers plant^{-1} in both the years. Treatment combination of D_3V_1 gave the highest number of total tillers plant^{-1} in both the years. The lowest number of total tillers plant^{-1} was found in D_1V_2 treatment combination in both the trials (Table 7a and 7b).

Total number of tillers plant^{-1} was varied significantly due to the interaction of late seeding and micronutrient in both the years. The highest total number of tillers plant^{-1} was observed in D_3M_3 treatment combination and the lowest was found in D_1M_0 treatment combination in both the years (Table 9a and 9b).

The interaction of variety and micronutrient had significant effect on total number of tillers plant^{-1} in both the years. The highest number of total tillers plant^{-1} was obtained in V_1M_3 treatment combination. The lowest total number of tillers plant^{-1} was found in V_2M_0 treatment combination in both the trials (Table 10a and 10b).

4.2.3 Number of effective tillers plant^{-1}

There was significant effect in respect of effective tillers plant^{-1} due to late seeding in both the years. Effective tillering tended to decrease generally as the sowing date was delayed. In 1st year, the maximum number of effective tillers plant^{-1} was recorded in 25th November (D_1) and the minimum was in 25th December (D_3). In 2nd year, the highest number of effective tillers plant^{-1} was found in 25th November (D_1) and the lowest was in 25th December (D_3).

Number of effective tillers plant^{-1} varied significantly due variety in both the years. The reasons of differences in producing effective tillers plant^{-1} might be due to genetic makeup of the varieties primarily influenced by heredity. V_2 gave the highest number of effective tillers plant^{-1} and V_1 treatment showed the lowest one in both the years.

Number of effective tillers plant^{-1} was affected significantly due to micronutrient levels in both the years. In 1st year, the highest number of effective tillers plant (5.200) was recorded in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest was (3.324) in control. In 2nd year, the highest number of effective tillers plant^{-1} (4.981) was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). The lowest number of effective tillers plant^{-1} was observed in control (M_0) (Table 8a and 8b).

The interaction effect of late seeding and variety was significant for effective tillers plant^{-1} in both the years. The highest number of effective tillers plant^{-1} was found in D_1V_2 treatment combination and the lowest was in D_3V_1treatment combination in both the years (Table 7a and 7b).

Number of effective tillers plant^{-1} showed significant variation by the interaction of late seeding and micronutrient in both the years. 25th December (D_3) sowing and without micronutrient application produced the lowest effective tillers plant^{-1}. The highest number of effective tillers plant^{-1} was found in D_1M_3 treatment combination in both the years. The lowest number of effective tillers plant^{-1} was obtained in D_3M_0 treatment combination in both the years (Table 9a and 9b).

The interaction of variety and micronutrient had significant effect on number of effective tillers plant in both the years. The highest number of effective tillers plant^{-1} was recorded in V_2M_3 treatment combination. The lowest number of effective tillers plant^{-1} was found in V_1M_0 treatment combination (Table 10a and 10b).

4.2.4 Spikelets spike^{-1}

The effect of late seeding heat stress condition was found to be significant in respect of number of spikelets spike^{-1} in both the years.

Significantly the highest number of spikelets spike^{-1} was obtained in 25th November (D_1) and the lowest was in 25th December (D_3) in both the years. High temperature stress degenerates mitochondria, changes the protein expression profiles, reduces AT accumulation, and oxygen uptake in imbibing wheat embryos, resulting in increased occurrence of loss of seed quality relating to seed mass, vigor, and germination (Balla *et al.* 2012; Hampton *et al.* 2013).

Number of spikelets spike^{-1} was significantly affected by varieties in both the years. In respect of variety, the highest number of spikelets spike^{-1} was found in BARI Gom28 (V_2) and the lowest number of spikelets spike^{-1} was recorded in BARI Gom26 (V_1) in both the years.

Number of spikelets spike^{-1} varied significantly due to micronutrient levels in both the years. It was noticed that combination of (B 1.25 kg ha^{-1} +Zn 5.30 kg ha^{-1}) (M_3) produced highest number of spikelets spike^{-1} and control (M_0) produced lowest number of spikelets spike^{-1} in both the years (Table 8a and 8b).

Sowing date and variety interacted significantly on the production of effect of spikelets spike^{-1} 2nd years (Table 7a and 7b).

The interaction effect of late seeding and micronutrient was found to be significant in respect of number of spikelets spike^{-1} in both the years. The highest number of spikelets spike^{-1} was observed in D_1M_3 treatment combination. The lowest values were obtained in D_3M_0 treatment combination in both the trails (Table 9a and 9b).

Spikelets spike^{-1} was significantly affected by the interaction of variety and micronutrient in both the years. The highest number of spikelets spike^{-1} was recorded in V_2M_3 treatment combination. The lowest number of spikelets spike^{-1} was found by V_1M_0 treatment combination (Table 10a and 10b).

4.2.5 Spike length

Spike length of both BARI Gom 26 (V_1) and BARI Gom 28 (V_2) were reduced due to heat stress. Spike length varied significantly due to late seeding heat stress condition in both the years. Numerically the longest spike was found in 25th November (D_1). The shortest one was obtained in 25th December (D_3) in both the trials.

Spike length was significantly affected by variety in 1st year. BARI Gom 28 (V_2) showed the best result where BARI Gom 26 (V_1) showed shorter spike length in both the trials.

Here, it can be stated that micronutrient had a contribution for longer spike length. Micronutrient levels had significant effect on spike length in both the years. Increased spike length was observed due to application the combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. From the above findings, it is concluded that the spike length was enhanced by Zn and B interaction. This result is agreed with that of Ziaeyan and Rajaie (2009). Mekkei and El- Haggan Eman (2014) observed that combination of micronutrients (Cu+ Fe+ Mn+ Zn) produced the highest values of spike length, number of grains $spike^{-1}$. Other workers have also reported that Zinc application improved spike length and shortest from control (Dewal and Pareek 2004 and Islam *et al.* 1999). The lowest value was recorded in control (M_0) in both the years (Table 8a and 8b).

Spike length show statistically significant variation by the interaction of late seeding and variety in both the years (Table 7a and 7b).

Significant variation was observed for spike length influenced by the Interaction effect of late seeding and micronutrient in both the trials (Table 9a and 9b)

In most of cases, the interaction effects of variety and micronutrient significantly increased spike length of both varieties. The interaction between variety and micronutrient splits was found to be significant in respect of spike length in both the years. Results revealed that the longest spike length was found in V_2M_3 treatment combination. The shortest spike length was obtained in V_2M_0 treatment combinations (Table 10a and 10b).

4.2.6 Number of grains spike^{-1}

Number of grains spike was significantly affected by late seeding heat stress condition in both the years. The number of grains spike^{-1} tended to decline as the date of sowing was delayed. The highest number of grain spike was found in 25th November (D_1) in both the years. The lowest number of grain spike^{-1} was recorded in 25th December (D_3) in both the trails. Pal *et al.* (1996) reported that the number of grains spike^{-1} gradually declined as the sowing date was delayed. However, the influence of heat stress on both the number and size of grains varies with the growth stages encountering heat stress. For instance, temperatures above 20°C between spike initiation and anthesis speed up the development of the spike but reduce the number of spikelets and grains per spike (Semenov 2009).

It was found that Number of grain spike^{-1} was found to be significant in respect of varieties in both the years. It was observed that BARI Gom 28 (V_2) showed the highest number of grain spike^{-1} and BARI Gom 26 (V_1) showed the lowest number of grain spike^{-1} in both the years.

Micro-nutrients levels had significant effect on number of grains spike^{-1} in both the years. Each level of micro-nutrients produced significantly different number of grains spike^{-1}. The results showed that the maximum number of grains spike^{-1} was produced by application of combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment and the minimum number of grains spike^{-1} was found at control (M_0) treatment in both the years (Table 8a and 8b). The combined positive effect of Zn and B interaction on number of grains spike^{-1} of wheat was reported by Ali *et al.*

(2009). The maximum number of grains spike^{-1} was probably attributed to reduction of sterility of wheat as B reduces male sterility of wheat. Similar results were also reported by Mandal (1987), Mandal and Das (1988) and Rahman (1989).

It was observed from the study that the interaction of late seeding and variety had no significant effect on number of grain spike^{-1} in both the trials. The highest number of grain spike^{-1} was obtained in D_1V_2 treatment combination and the lowest was D_3V_1 treatment combination in both the years (Table 7a and 7b). Even high temperature of above 30°C during floret development may cause complete sterility in wheat depending on genotypes (Kaur and Behl 2010).

Micronutrient untreated stamens and pistils of wheat plants have poor growth. On the other hand, development of anther and microspore in micronutrient untreated wheat plant has poor pollen adhesion and germination in comparison with treated wheat plants as well as ovule viability and longevity disturbed (Plate 8.). In wheat, high temperature stress (more than 30 degree celsius) from early meiosis to pollen maturity has a damaging effect on the viability of pollen grain, resulting in a failure of fertilization and thus in a reduction in seed set (Saini and Aspinall 1982).

Number of grain spike^{-1} varied significantly due to the interaction of late seeding and micronutrient in both the years. The highest number of grain spike^{-1} was obtained in D_1M_3 treatment combination. The lowest number of grain spike^{-1} was found in D_3M_0 treatment combination in both the years (Table 9a and 9b).

Under the present study, number of grain spike^{-1} was significantly affected by the interaction of variety and micronutrient in both the trials. Significantly the highest number of grain spike^{-1} was observed in V_2M_3 treatment combination in both the trials. The lowest number of grain spike^{-1} was recorded in V_1M_0 treatment combination in both the trials (Table 10a and 10b).

4.2.7 1000-grain weight

Weight of 1000 grain is an important yield contributing character. Higher 1000 grain weight indicates more healthy seeds and resulted higher grain yield ha^{-1}. Thousand grain weight differed significantly due to late seeding heat stress condition in both the years. In 1st year, the highest 1000-grain weight (40.32) was found in 25th November (D_1) and it was lowest (37.805) when sowing was done lately in 25th December (D_3). In 2nd year, the highest 1000-grain weight (37.821) was observed in 25th November (D_1). The lowest 1000-grain weight (35.211) was observed in 25th December (D_3). The delayed sowing caused significant reduction in grain weight due to high temperature at grain filling stage. Singh *et al.* (1993) indicated that late sowing (16 and 30 December) significantly reduced thousand grain weight. Patel *et al.* (1982) pointed out that higher seed weight was observed in early (20 November and 5 December) sowings. Joshi and Sing (1993) mentioned that late sowing affected 1000-grain weight. These finding is also in agreement with the findings of Sing and Dixit (1985).

Thousand grain weight was also significantly affected due to varieties in both the years. The thousand grain weight varied with the varieties showing that grains were not equally developed in two varieties. The highest 1000-grain weight was observed in BARI Gom 26 (V_1) and the lowest was in BARI Gom 28 (V_2) in both the years. Kenbaev and Sade (2002) and Hosseini (2006) reported that yield components increased with the increase in Zn application.

Thousand grain weight was significantly affected by micro-nutrients levels in both the years. In 1st year, the highest 1000-grain weight (44.906 g) was observed in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest (31.97 g) was found in control. In 2nd year, the highest 1000-grain weight (42.937 g) was recorded in combination with (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest were found in control (M_0) (Table 8a and 8b). Zeidan *et al.* (2010) showed that 1000 grains weight was significantly increased with application of foliar application of Zn. Such results are in conformity with the findings of Mete *et al.* (2005) and Soylu *et al.* (2005) who reported that the weight of 1000 grain increased significantly with the increased B fertilization. The above results indicate that the 1000 grain weight was enhanced by Zn and B interaction. This combined positive effect of Zn and B interaction on 1000 grain weight of wheat was also reported by Ali *et al.* (2009).

The interaction effect of late seeding and variety was significant for 1000-grain weight in both the years. The highest number of 1000-grain weight was obtained in D_1V_1 treatment combination and the lowest was D_3V_2 treatment combination in both the years (Table 7a and 7b).

Thousand grain weight show significant variation by the interaction of late seeding and micronutrient in both the years. The highest thousand grain weight obtained in D_1M_3 treatment combination. The lowest thousand grain weight was found in D_3M_0 treatment combination in both the years (Table 9a and 9b).

Thousand grain weight was significant due to the interaction of variety and micronutrient. The highest thousand grain weight obtained in V_1M_3 treatment combination. The lowest thousand grain weight was found in V_2M_0 treatment combination in both the years (Table 10a and 10b).

4.2.8 Grain yield

Grain yield differed significantly due to late seeding heat stress condition in both the years. In 1st year, the highest grain yield (3.93 t ha^{-1}) was recorded in 25th November (D_1) and the lowest (3.54 t ha^{-1}) was in 25th December (D_3) (table 89a). In 2nd year, the highest grain yield (3.58 t ha^{-}

^{1}) was produced by 25th November (D_1) treatment. The lowest grain yield (3.10 t ha^{-1}) was observed in 25th December (D_3). Razzaque and Hossain (1991) from the Wheat Research Centre, Dinajpur reported that yield had tremendously declined when sowing was done after 1st December. Recently, Song *et al.* (2015) observed a significant reduction in the rate of grain filling in wheat cultivars at day to night temperature of 32 to 22° C when compared with that of 25 to 15°C. However, the grain growth rate and duration decreased in plants having different grain weight stability (Vijayalakshmi *et al.* 2010). Day to night high temperature of 31 to 20°C may also cause shrinking of grains resulting from changing structures of the aleurone layer and cell endosperm (Dias *et al.* 2008).

Varieties showed significant variation in grain yield for both the years. Significantly the highest grain yield was recorded in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1) in both the years.

Grain yield is the main achievement of a crop production. Application of micronutrient played a significant role on the yield and yield components of wheat. Yield components were influenced significantly due to application of micronutrient. Result showed that micronutrient levels had significant effect on grain yield in both the years. In 1st year, the highest grain yield (4.75 t ha^{-1}) was observed in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). The lowest grain yield (2.64 t ha^{-1}) was found in control (M_0) (Table 8a and 8b). In 2nd year, the highest grain yield (4.35 t ha^{-1}) was obtained in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). This was followed by Zn (5.30 kg ha^{-1}) (M_2) and B (1.25 kg ha^{-1}) (M_1). The lowest grain yield (2.11 t ha^{-1}) was observed in control (M_0) (Table 8a and 8b).The boron fertilizer increased the production of more grains $spike^{-1}$ which might be the cause of more grain yield. Similar results were also reported by Abedin *et al.* (1994). These results agreed with Torun *et al*. (2001) and Grewal *et al*. (1997) who reported that increased wheat production with application of zinc over control. This result was in accordance with that of Mandal (1987), Galrao and Sousa (1988), Rahman (1989), BINA, (1993) and Jahiruddin *et al.* (1995).

Zn in conjunction with B produced higher grain yield which is cleared from the trial. Similar results were also published by Arif *et al.* (2006).

The interaction of late seeding and variety had significant effect on grain yield in both the trails. The highest grain yield was found in D_1V_2 treatment combination in both years. The lowest grain yield was obtained in D_3V_1 treatment combination in both the years (Table 7a and 7b). 37 to 28°C day to night from 10 to 20 days post anthesis until maturity shortened grain filling period and maturity; drastically reduced fresh weight, dry weight, protein, and starch content in grain; reduced grain size and yield Hurkman *et al.* (2009) 34 to 26°C (day to night),16 days.

In general, late sowing wheat varieties faces severe temperature stress, shortens the heading and maturity duration, ultimately affecting final yield and grain quality (Hossain and Teixeira de Silva 2012; Hakim *et al.* 2012). Grain yield varied significantly due to the interaction of late seeding and micronutrient in 1st year and was not significant in 2nd year. In 1st year the highest grain yield (4.94 t ha^{-1}) was recorded in D_1M_3 treatment combination. The lowest grain yield (2.44 t ha^{-1}) was found in D_3M_0 treatment combination (Table 9a and 9b). Plants exposed with drought significantly decreased grain yield of both BARI Gom 26 (V_1) and BARI Gom 28 (V_2). At the grain-filling stage increased leaf temperature; decreased leaf chlorophyll and maximum quantum yield of photo system-II; decreased in individual grain weight and grain yield Pradhan and Prasad (2015).

The interaction of variety and micronutrient significantly affect the grain yield in both the years. The highest grain yield was found in V_2M_3 treatment combination in both the years. The lowest grain yield was obtained in V_1M_0 treatment combination in both the years (Table 10a and 10b).

4.2.9 Biological yield

Biological yield varied significantly due to late seeding heat stress condition in both the years. The highest biological yield was recorded in 25^{th} November (D_1) and lowest was found in 25^{th} December (D_3) in both the years.

Biological yield was not significantly influenced by varieties in both the years. Results showed that BARI Gom 28 (V_2) gave the highest biological yield and BARI Gom 26 (V_1) gave the lowest biological yield in both the years.

Micro-nutrients levels had significant effect on biological yield in both the years. The highest biological yield was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. The lowest biological yield was obtained in control (M_0) in both the years (Table 8a and 8b).

The interaction between late seeding and variety was found to be significant in respect of biological yield in both the years. The highest biological yield was found in D_1V_2 treatment combination. The lowest biological yield was observed in D_3V_2 treatment combination in both the years (Table 7a and 7b).

The interaction effect of late seeding and micronutrient was significant for biological yield in both the years. The highest biological yield was obtained in D_1M_3 treatment combination and the lowest (3.31 t ha^{-1}) was found in D_3M_0 treatment combination in both the years (Table 9a and 9b).

The interaction due to variety and micronutrient significantly affect the biological yield in both the years. The highest biological yield was obtained in V_2M_3 treatment combination and the lowest biological yield was found in V_2M_0 treatment combination in both the years (Table 10a and 10b).

Table 7a. Interaction effect of late seeding and variety on yield and yield contributing characters of wheat in 1st year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant-1	Spikelets Spike-1	Spike length (cm)	Grains Spike-1	1000 grain weight (g)	Grain yield (t ha-1)	Biological Yield (t ha-1)
D_1V_1	91.729b	4.972e	4.472b	20.383	10.047b	45.585	**40.687a**	3.884b	8.836b
D_1V_2	**92.441a**	4.882f	**4.558a**	**20.663**	**10.17a**	**46.173**	39.953b	**3.984a**	**9.174a**
D_2V_1	90.555c	5.166c	4.304d	19.983	9.911c	44.376	39.407c	3.694d	8.444c
D_2V_2	90.436c	5.076d	4.386c	20.196	9.919c	45.018	38.606d	3.792c	8.437c
D_3V_1	89.370d	**5.374a**	4.119f	19.562	9.757d	42.932	38.199e	3.494f	8.05d
D_3V_2	88.501e	5.267b	4.216e	19.802	9.64e	43.822	37.411f	3.587e	7.811e
LS	0.010	0.010	0.010	NS	0.010	NS	0.010	0.010	0.010
CV	5.08	5.79	5.10	4.80	5.10	4.94	5.42	6.23	5.35

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Table 7b. Interaction effect of late seeding and variety on yield and yield contributing characters of wheat in 2nd year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant-1	Spikelets Spike-1	Spike length (cm)	Grains Spike-1	1000 grain weight (g)	Grain yield (t ha-1)	Biological Yield (t ha-1)
D_1V_1	89.365a	5.064e	4.145b	19.133b	10.789b	45.036	**38.189a**	3.525b	8.535b
D_1V_2	**89.931a**	4.977f	**4.241a**	**19.344a**	**10.933a**	**45.525**	37.452b	**3.635a**	**8.773a**
D_2V_1	88.233b	5.323c	3.963d	18.602d	10.52c	43.496	36.855c	3.308d	8.092c
D_2V_2	88.071b	5.22d	4.054c	18.869c	10.582c	44.19	36.211d	3.435c	8.101c
D_3V_1	86.888c	**5.538a**	3.776f	18.061f	10.333d	42.277	35.59e	3.021f	7.714d
D_3V_2	85.929d	5.428b	3.865e	18.28e	10.212e	42.734	34.831f	3.191e	7.536e
LS	0.010	0.010	0.010	0.010	0.010	NS	0.010	0.050	0.010
CV	5.03	5.31	6.01	5.50	4.83	5.30	5.53	5.76	6.62

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Table 8a. Effect of micronutrient on yield and yield contributing characters of wheat in 1st year

Parameter / Micronutrient	Plant height (cm)	Total tillers plant^{-1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
M_0	79.135c	3.981d	3.324d	17.378d	8.552d	36.952d	31.97d	2.644d	5.31d
M_1	89.415b	4.861c	4.150c	19.618c	9.666c	43.152c	38.132c	3.474c	7.614c
M_2	94.694a	5.481b	4.696b	20.874b	10.324b	47.146b	41.168b	4.081b	9.479b
M_3	**98.778a**	**6.168a**	**5.200a**	**22.522a**	**11.087a**	**51.354a**	**44.906a**	**4.759a**	**11.431a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.08	5.79	5.10	4.80	5.10	4.94	5.42	6.23	5.35

Table 8b. Effect of micronutrient on yield and yield contributing characters of wheat in 2nd year

Parameter / Micronutrient	Plant height (cm)	Total tillers plant^{-1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
M_0	76.954d	4.041d	2.924d	15.520d	8.938d	34.975d	28.357d	2.113d	5.411d
M_1	87.357c	4.94c	3.753c	18.114c	10.164c	42.962c	35.686c	3.194c	7.465c
M_2	91.6b	5.582b	4.372b	19.638b	11.047b	46.942b	39.107b	3.744b	8.951b
M_3	**96.368a**	**6.47a**	**4.981a**	**21.586a**	**12.097a**	**50.626a**	**42.937a**	**4.359a**	**10.673a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.03	5.31	6.01	5.50	4.83	5.30	5.53	5.76	6.62

Table 9a. Interaction effect of late seeding and micronutrient on yield and yield contributing characters of Wheat in 1st year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant-1	Spikelets Spike-1	Spike length (cm)	Grains Spike-1	1000 grain weight (g)	Grain yield (t ha-1)	Biological Yield (t ha-1)
D_1M_0	81.207ef	3.779g	3.527h	17.753ef	8.745fg	38.206gh	33.963gh	2.848h	5.757h
D_1M_1	91.466bcd	4.656f	4.355ef	19.986cd	9.871de	44.646def	39.193def	3.675ef	8.205ef
D_1M_2	95.492abc	5.281cde	4.842bcd	21.334bc	10.53a-d	48.076bcd	42.245bcd	4.272bc	10.157c
D_1M_3	**100.175a**	5.992ab	**5.337a**	**23.019a**	**11.288a**	**52.588a**	**45.879a**	**4.941a**	**11.899a**
D_2M_0	79.176f	3.988g	3.338hi	17.43f	8.561g	37.11h	31.933hi	2.639hi	5.321hi
D_2M_1	89.386cd	4.866ef	4.139fg	19.612d	9.675de	43.154ef	38.147ef	3.474fg	7.612fg
D_2M_2	94.9a-d	5.476cd	4.7cde	20.849bcd	10.339bcd	47.181cd	41.115cde	4.093cd	9.373d
D_2M_3	98.521ab	6.155ab	5.203ab	22.466ab	11.085ab	51.343ab	44.832ab	4.766a	11.456ab
D_3M_0	77.021f	4.177g	3.108i	16.951f	8.352g	35.538h	30.014i	2.445i	4.851i
D_3M_1	87.394de	5.060def	3.957g	19.256de	9.453ef	41.657fg	37.055fg	3.273g	7.025g
D_3M_2	93.69a-d	5.686bc	4.546de	20.44cd	10.101cde	46.182de	40.144def	3.877de	8.907de
D_3M_3	97.638ab	**6.359a**	5.059abc	22.081ab	10.888abc	50.131abc	44.007abc	4.569ab	10.939b
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.08	5.79	5.10	4.80	5.10	4.94	5.42	6.23	5.35

Table 9b. Interaction effect of late seeding and micronutrient on yield and yield contributing characters of wheat in 2nd year

Parameter / Interaction	Plant height (cm)	Total tillers plant-^{1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
D_1M_0	78.761ef	3.825h	3.135g	15.97g	9.133hi	36.969g	30.213g	2.46	5.913h
D_1M_1	89.297bcd	4.748g	3.946ef	18.64def	10.426efg	44.643def	37.009def	3.417	7.98ef
D_1M_2	92.563a-d	5.357def	4.58bc	20.152bcd	11.299bcd	47.984a-d	39.934bcd	3.867	9.536cd
D_1M_3	**97.972a**	6.151bc	**5.112a**	**22.192a**	**12.586a**	**51.526a**	**44.127a**	**4.575**	**11.188a**
D_2M_0	77.075f	4.043h	2.924gh	15.64g	8.941i	34.781g	28.178gh	2.138	5.391hi
D_2M_1	87.571cd	4.933fg	3.759f	18.077ef	10.159fg	43.097ef	35.891ef	3.21	7.441fg
D_2M_2	91.648a-d	5.576de	4.359cd	19.71cde	11.058cde	46.862b-e	39.205cde	3.768	8.847de
D_2M_3	96.314ab	6.533ab	4.992a	21.514ab	12.04ab	50.631ab	42.858ab	4.37	10.707ab
D_3M_0	75.025f	4.255h	2.712h	14.951g	8.739i	33.174g	26.681h	1.741	4.93i
D_3M_1	85.201de	5.14efg	3.553f	17.625f	9.907gh	41.146f	34.156f	2.954	6.975g
D_3M_2	90.589a-d	5.812cd	4.177de	19.053def	10.784def	45.981cde	38.182de	3.596	8.47e
D_3M_3	94.818abc	**6.725a**	4.84ab	21.053abc	11.661bc	49.721abc	41.825abc	4.132	10.126bc
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	NS	0.010
CV	5.03	5.31	6.01	5.50	4.83	5.30	5.53	5.76	6.62

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Table 10a. Interaction effect of variety and micronutrient on yield and yield contributing characters of wheat in 1st year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
V_1M_0	79.367c	4.037d	3.27d	17.264d	8.570c	36.619d	32.446e	2.597d	5.345d
V_1M_1	89.660b	4.906c	4.109c	19.515c	9.673b	42.757c	38.567cd	3.424c	7.63c
V_1M_2	94.683ab	5.533b	4.654b	20.767bc	10.301b	46.786b	41.512b	4.034b	9.406b
V_1M_3	98.496a	**6.206a**	5.161a	22.358a	11.076a	51.03a	**45.199a**	4.708a	11.392a
V_2M_0	78.902c	3.925d	3.379d	17.492d	8.535c	37.285d	31.494e	2.69d	5.274d
V_2M_1	89.171b	4.815c	4.191c	19.721bc	9.660b	43.547c	37.696d	3.524c	7.599c
V_2M_2	94.705ab	5.428b	4.738b	20.981b	10.346b	47.507b	40.825bc	4.127b	9.552b
V_2M_3	**99.06a**	6.13a	**5.238a**	**22.686a**	**11.098a**	**51.678a**	44.613a	**4.809a**	**11.471a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.08	5.79	5.10	4.80	5.10	4.94	5.42	6.23	5.35

Table 10b. Interaction effect of variety and micronutrient on yield and yield contributing characters of wheat in 2nd year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
V_1M_0	77.117c	4.094d	2.868d	15.435e	8.947d	34.565d	28.796d	2.01d	5.452d
V_1M_1	87.634b	4.992c	3.7c	18.002d	10.182c	42.662c	36.152c	3.132c	7.498c
V_1M_2	91.561ab	5.634b	4.324b	19.494bc	11.023b	46.758b	39.355b	3.701b	8.886b
V_1M_3	96.335a	**6.512a**	4.953a	21.462a	12.037a	50.428a	**43.21a**	4.297a	10.618a
V_2M_0	76.791c	3.988d	2.98d	15.606e	8.928d	35.384d	27.919d	2.216d	5.371d
V_2M_1	87.079b	4.888c	3.805c	18.226cd	10.146c	43.262c	35.219c	3.256c	7.432c
V_2M_2	91.638ab	5.529b	4.42b	19.782b	11.071b	47.127b	38.858b	3.787b	9.016b
V_2M_3	**96.4a**	6.427a	**5.009a**	**21.71a**	**12.157a**	**50.824a**	42.663a	**4.421a**	**10.729a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.03	5.31	6.01	5.50	4.83	5.30	5.53	5.76	6.62

Table 11a. Interaction effect of late seeding, variety and micronutrient on yield and yield contributing characters of wheat in 1st year

Parameter / Interaction	Plant height (cm)	Total tillers plant-^{1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological Yield (t ha^{-1})
$D_1V_1M_0$	80.744d-h	3.821 p	3.482 mn	17.641 g-j	8.689 g-j	38.062 j-m	34.348 h-l	2.791 mno	5.634 mn
$D_1V_1M_1$	91.022a-e	4.709 j-n	4.316 g-k	19.863 c-g	9.791 c-h	44.282 e-h	39.494 d-h	3.635 g-k	7.959 hij
$D_1V_1M_2$	95.424abc	5.318 e-k	4.8 b-g	21.216 a-e	10.459 a-e	47.717 a-g	42.676 a-f	4.221 c-f	9.985 def
$D_1V_1M_3$	99.727ab	6.038 a-e	5.289 ab	22.813 ab	11.249 ab	52.278 ab	**46.23 a**	4.889 ab	11.764 ab
$D_1V_2M_0$	81.669d-h	3.736 p	3.571 lmn	17.866 f-j	8.8 f-j	38.349 i-m	33.578 i-l	2.905 l-o	5.88 lm
$D_1V_2M_1$	91.911a-d	4.602 k-o	4.394 f-k	20.108 c-f	9.951 b-g	45.009 d-h	38.892 e-h	3.716 f-k	8.451 ghi
$D_1V_2M_2$	95.560abc	5.243 f-k	4.883 a-f	21.453 a-e	10.6 a-e	48.436 a-f	41.814 a-g	4.324 b-e	10.33 cde
$D_1V_2M_3$	**100.624 a**	5.945 a-f	**5.385 a**	**23.225 a**	**11.328 a**	**52.898 a**	45.528 ab	**4.993 a**	**12.034 a**
$D_2V_1M_0$	79.697 e-h	4.052 nop	3.282 n	17.343 hij	8.593 hij	36.834 klm	32.427 jkl	2.6 o	5.464 mn
$D_2V_1M_1$	89.920a-f	4.903 h-l	4.084 i-l	19.567 d-h	9.721 d-h	42.776 g-j	38.65 e-i	3.417 i-l	7.726 ijk
$D_2V_1M_2$	94.546 abc	5.53 c-i	4.677 c-h	20.729 b-e	10.287 a-e	46.974 b-g	41.512 a-g	4.049 d-h	9.241 fg
$D_2V_1M_3$	98.058 abc	6.182 abc	5.175 abc	22.294 abc	11.041 abc	50.921 abc	45.04 abc	4.709 abc	11.346 abc
$D_2V_2M_0$	78.655 fgh	3.924 op	3.394 n	17.517 g-j	8.528 hij	37.387 j-m	31.439 kl	2.677 no	5.179 mn
$D_2V_2M_1$	88.852 a-g	4.83 i-m	4.194 h-k	19.657 d-h	9.629 d-i	43.532 f-i	37.644 f-i	3.53 h-k	7.498 ijk
$D_2V_2M_2$	95.255 abc	5.422 d-j	4.724 c-h	20.969 a-e	10.391 a-e	47.387 a-g	40.718 b-g	4.136 c-g	9.505 efg
$D_2V_2M_3$	98.983 ab	6.128 a-d	5.231 abc	22.639 ab	11.129 ab	51.765 ab	44.625 a-d	4.824 ab	11.566 ab
$D_3V_1M_0$	77.660 gh	4.239 l-p	3.045 n	16.808 j	8.426 ij	34.96 m	30.562 l	2.4 o	4.938 mn
$D_3V_1M_1$	88.039 b-g	5.107 g-k	3.928 klm	19.114 e-j	9.508 e-j	41.212 h-l	37.558 f-j	3.219 k-n	7.203 jk
$D_3V_1M_2$	94.080 abc	5.752 a-g	4.484 e-j	20.358 b-e	10.157 a-e	45.667 c-h	40.346 b-g	3.832 e-j	8.993 fgh
$D_3V_1M_3$	97.701 abc	**6.399 a**	5.02 a-e	21.968 a-d	10.937 a-d	49.89 a-e	44.328 a-d	4.527 a-d	11.065 abc
$D_3V_2M_0$	76.382 h	4.115 m-p	3.172 n	17.094 ij	8.278 j	36.117 lm	29.466 l	2.489 o	4.763 n
$D_3V_2M_1$	86.749 c-h	5.014 g-k	3.985 j-m	19.398 e-i	9.398 e-j	42.101 g-k	36.551 g-k	3.327 j-m	6.847 kl
$D_3V_2M_2$	93.299 abc	5.62 b-h	4.608 d-i	20.523 b-e	10.046 a-f	46.697 b-h	39.942 c-g	3.921 e-i	8.821 gh
$D_3V_2M_3$	97.574 abc	6.318 ab	5.098 a-d	22.193 abc	10.838 a-d	50.371 a-d	43.686 a-e	4.61 a-d	10.814 bcd
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.08	5.79	5.10	4.80	5.10	4.94	5.42	6.23	5.35

Table 11b. Interaction effect of late seeding, variety and micronutrient on yield and yield contributing characters of wheat in 2nd year

Parameter / Interaction	Plant height (cm)	Total tillers plant-1	Effective tillers plant-1	Spikelets Spike-1	Spike length (cm)	Grains Spike-1	1000 grain weight (g)	Grain yield (t ha-1)	Biological Yield (t ha-1)
$D_1V_1M_0$	78.165 e-i	3.885 l	3.08 lmn	15.915 h-k	9.079 klm	36.528 gh	30.61 ijk	2.378 mn	5.812 mn
$D_1V_1M_1$	89.113 a-e	4.793 hij	3.884 g-j	18.565 efg	10.353 f-j	44.538 b-e	37.391 d-h	3.373 g-j	7.87 g-k
$D_1V_1M_2$	92.451 abc	5.413 d-h	4.525 a-f	19.984 a-g	11.246 b-h	47.77 abc	40.137 a-f	3.826 c-g	9.375 c-f
$D_1V_1M_3$	97.73 a	6.164 abc	5.091 a	22.066 ab	12.478 ab	51.308 a	**44.62 a**	4.522 ab	11.084 a
$D_1V_2M_0$	79.357 d-i	3.764 l	3.191 k-n	16.025 h-k	9.187 j-m	37.41 fgh	29.815 jk	2.543 lm	6.015 lmn
$D_1V_2M_1$	89.481 a-d	4.703 ijk	4.008 f-j	18.715 efg	10.499 e-i	44.747 b-e	36.628 e-h	3.462 f-j	8.089 f-k
$D_1V_2M_2$	92.674 abc	5.301 d-i	4.635 a-e	20.32 a-f	11.351 b-g	48.199 abc	39.73 a-g	3.909 c-f	9.698 b-e
$D_1V_2M_3$	**98.213 a**	6.139 abc	**5.132 a**	**22.317 a**	**12.695 a**	**51.745 a**	43.635ab	**4.628 a**	**11.291 a**
$D_2V_1M_0$	77.597 f-i	4.096 kl	2.861 n	15.551 ijk	8.969 klm	34.275 h	28.728 k	2.049 no	5.535 n
$D_2V_1M_1$	88.017 a-f	4.98 f-i	3.712 h-k	17.924 f-i	10.228 g-k	42.604 c-f	36.298 fgh	3.157 ijk	7.53 h-k
$D_2V_1M_2$	91.348 abc	5.637 c-f	4.3 c-h	19.57 b-g	10.98 c-i	46.68 a-e	39.384 b-g	3.738 d-h	8.724 e-h
$D_2V_1M_3$	95.97 abc	6.578 a	4.978 ab	21.362 a-d	11.902 a-d	50.426 ab	43.011 ab	4.29 abc	10.579 abc
$D_2V_2M_0$	76.554 ghi	3.99 l	2.987 mn	15.729 h-k	8.912 lm	35.287 h	27.628 k	2.226 mno	5.248 n
$D_2V_2M_1$	87.125 a-g	4.885 g-j	3.806 hij	18.23 fgh	10.089 g-l	43.59 cde	35.485 fgh	3.264 h-k	7.352 ijk
$D_2V_2M_2$	91.948 abc	5.515 c-g	4.417 b-g	19.85 a-g	11.136 c-i	47.045 a-d	39.025 b-g	3.799 d-g	8.97 d-g
$D_2V_2M_3$	96.657 ab	6.488 ab	5.007 ab	21.667 abc	12.189 abc	50.837 a	42.705 abc	4.45 ab	10.834 ab
$D_3V_1M_0$	75.589 hi	4.3 jkl	2.662 n	14.838 k	8.794 m	32.893 h	27.049 k	1.603 p	5.01 n
$D_3V_1M_1$	85.772 b-h	5.202 d-i	3.505 j-m	17.518 g-j	9.965 h-m	40.843 efg	34.768 ghi	2.866 kl	7.095 jkl
$D_3V_1M_2$	90.885 abc	5.853 bcd	4.147 e-i	18.929 d-g	10.843 d-i	45.824 a-e	38.545 b-h	3.538 f-i	8.56 e-i
$D_3V_1M_3$	95.304 abc	**6.795 a**	4.789 a-d	20.958 a-e	11.733 a-e	49.55 ab	42 a-d	4.078 b-e	10.19 a-d
$D_3V_2M_0$	74.461 i	4.21 jkl	2.763 n	15.064 jk	8.685 m	33.455 h	26.313 k	1.879 op	4.849 n
$D_3V_2M_1$	84.631 c-i	5.077 e-i	3.601 i-l	17.731 f-i	9.849 i-m	41.45 d-g	33.544 hij	3.043 jk	6.854 klm
$D_3V_2M_2$	90.293 a-d	5.77 cde	4.208 d-h	19.176 c-g	10.725 d-i	46.138 a-e	37.819 c-h	3.655 e-h	8.38 e-j
$D_3V_2M_3$	94.331 abc	6.655 a	4.89 abc	21.148 a-e	11.588 a-f	49.892 ab	41.65 a-e	4.186 a-d	10.062 a-d
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	5.03	5.31	6.01	5.50	4.83	5.30	5.53	5.76	6.62

4.3 Simple correlation between yield and yield contributing characters of wheat

Yield is the expression as a whole of the performance of various yield contributing characters and the results of interaction among them. Hence, it is of utmost importance to know the quality of interrelationship among the yield and yield contributing characters. The correlation co-efficient is done to know the relations between the different yield and yield characters at harvest. The Simple correlation matrix of the selected parameters is presented in Appendix VA and VB.

The correlation co-efficient result indicated that in 2015-16, plant height was positively correlated with number of total tillers plant^{-1}, effective tillers plant^{-1}, number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Number of total tillers plant^{-1} was positively associated with effective tillers plant^{-1}, number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Effective tillers plant^{-1} was positively related with number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Spikelets spike^{-1} was positively associated with spike length, grains spike^{-1}, 1000-grain weight and grain yield. Spike length was positively related with grains spike^{-1}, 1000-grain weight and grain yield. Grains spike^{-1} was positively correlated with 1000-grain weight and grain yield. 1000-grain weight was positively related with grain yield.

On the other hand in 2017-18, plant height was positively correlated with number of total tillers plant^{-1}, effective tillers plant^{-1}, number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Number of total tillers plant^{-1} was positively associated with effective tillers plant^{-1}, number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Effective tillers plant^{-1} was positively related with number of spikelets spike^{-1}, spike length, grains spike^{-1}, 1000-grain weight and grain yield. Spikelets spike^{-1}was positively associated with spike length, grains spike^{-1}, 1000-grain weight and grain yield. Spike length was positively related with grains spike^{-1}, 1000-grain weight and grain yield. Grains spike^{-1} was positively correlated with 1000-grain weight and grain yield. 1000-grain weight was positively related with grain yield.

A significant positive correlation between grain yield plant^{-1} and 100-seed weight was observed in wheat (Islam 1977). Grain number and grain weight were significantly correlated with grain yield (Labuschange and Van-Deventer 1992).

The correlation between total tillers plant^{-1}, effective tillers plant^{-1}, spikelets spike^{-1}, grains spike^{-1}and 1000-grain weight with grain yield are briefly described below with graphical form -

Correlation between total tillers plant^{-1} versus grain yield

The degree of relationship between total tillers plant^{-1} and grain yield was studied (Figure 38). The result revealed that effective tillers plant^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r = 0.926** in 1st year and r = 0.894** in 2nd year. The positive slope indicates positive relationship which means that an increase in the number of effective tillers plant^{-1} will lead to an increase in grain yield.

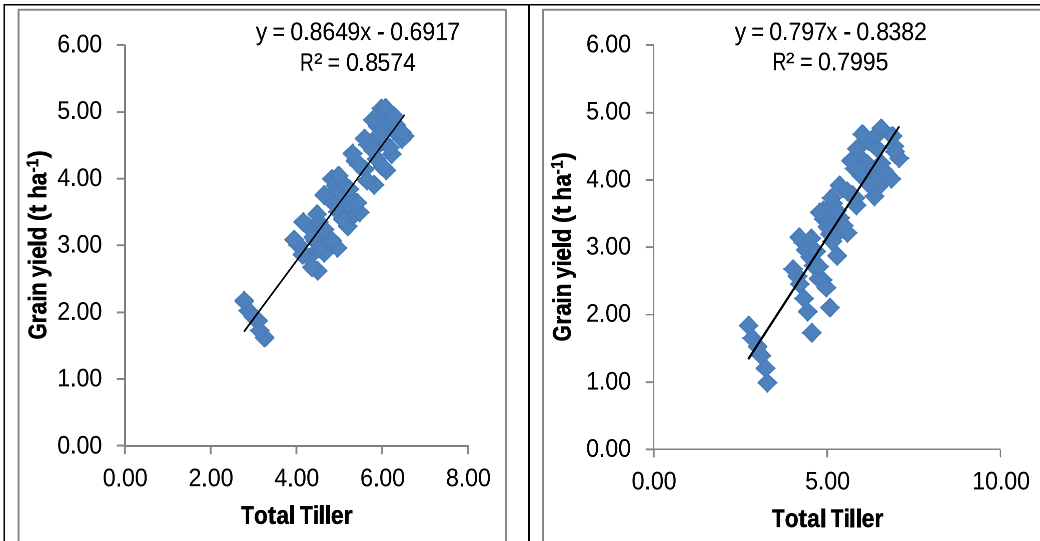


Figure 38: Correlation between total tillers plant^{-1} and grain yield in 2015-2016 and in 2017-2018

Correlation between effective tillers plant^{-1} versus grain yield

The degree of relationship between effective tillers plant^{-1} and grain yield of wheat was studied (Figure 39). The result revealed that effective tillers plant^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation coefficient r = 0.992** in 1st year and r = 0.988** in 2nd year. The positive slope indicates positive relationship, which means that an increase in the number of effective tillers plant^{-1} will lead to an increase in grain yield of wheat.

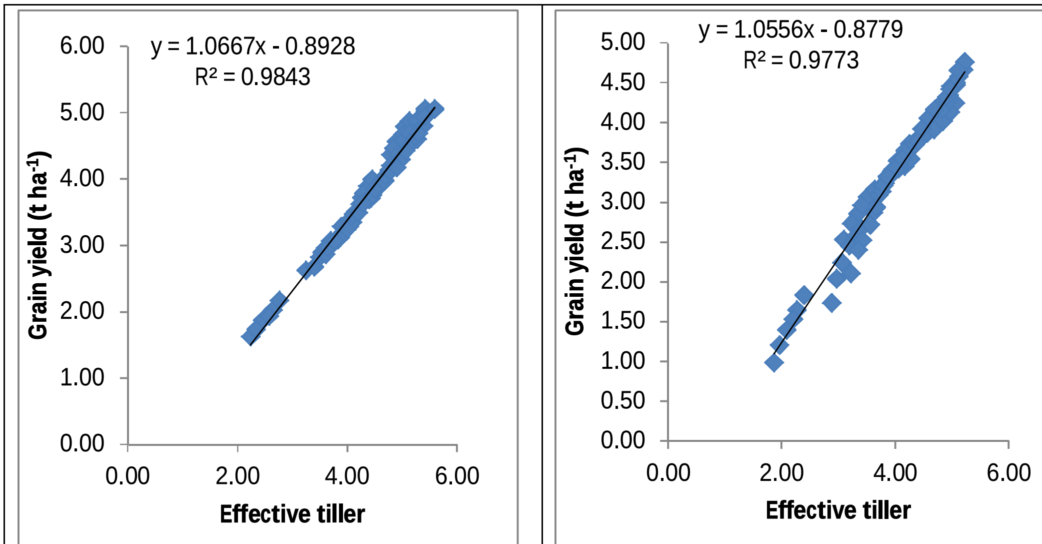


Figure 39: Correlation between effective tillers plant^{-1} and grain yield in 2015-2016 and in 2017-2018

Correlation between spikelets spike^{-1} versus grain yield

The degree of relationship between number of spikelets spike^{-1} and grain yield was studied (Figure 40). The result revealed that spikelets spike^{-1} and grain yield have a significant positive relationship at 1% level of significance. The correlation co-efficient r = 0.939** in 1st year and r = 0.956** in 2nd year. The positive slope indicates positive relationship which means that an increase in number of spikelets spike^{-1} will lead to an increase in grain yield.

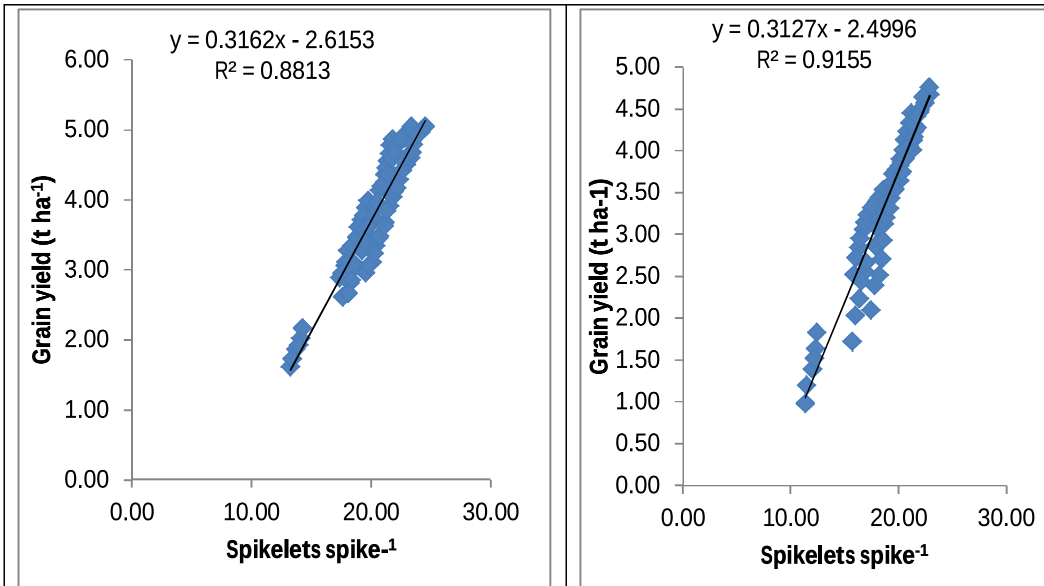


Figure 40: Correlation between spikelets spike^{-1} and grain yield in 2015-2016 and in 2017-2018

Correlation between grains spike^{-1} versus grain yield

The degree of relationship between grains spike^{-1}and grain yield of wheat was studied (Figure 41). The result revealed that grains spike^{-1}and grain yield have a significant positive relationship at 1% level of significance. The correlation coefficient r = 0.958** in 1st year and r = 0.971** in 2nd year. The positive slope indicates positive relationship, which means that an increase in the number of grains spike^{-1} will leads to an increase in grain yield of wheat.

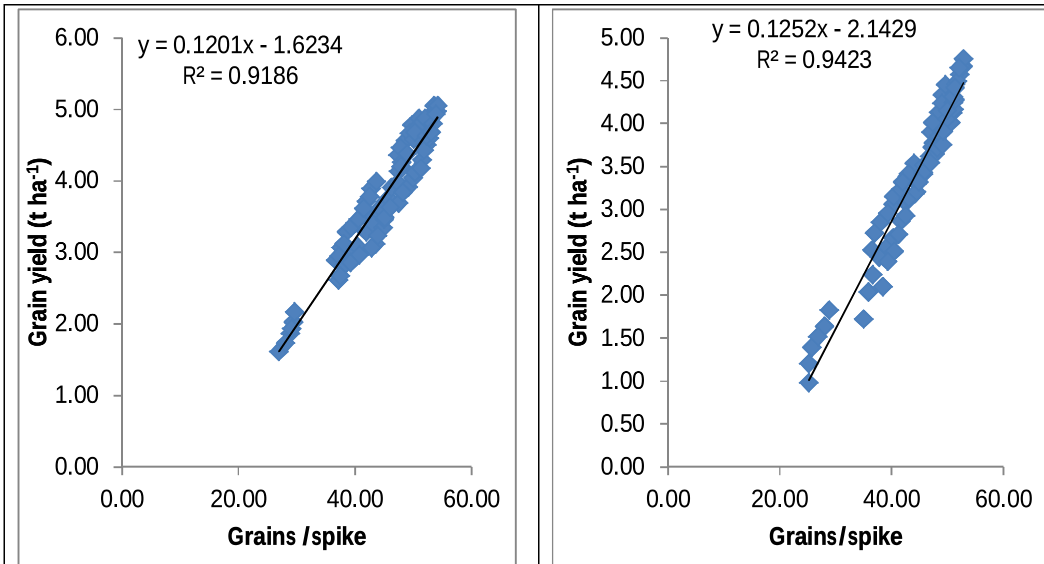


Figure 41: Correlation between grains spike^{-1} and grain yield in 2015-2016 and in 2017-2018

Correlation between 1000-grain weight versus grain yield

Finally, the degree of relationship between 1000-grain weight and grain yield of wheat was studied (Figure 42). The result revealed that 1000-grain weight and grain yield have a significant positive relationship at 1% level of significance. The correlation coefficient r = 0.958** in 1st year and r = 0.965** in 2nd year. The positive slope indicates positive relationship which means that an increase in 1000-grain weight will lead to an increase in grain yield.

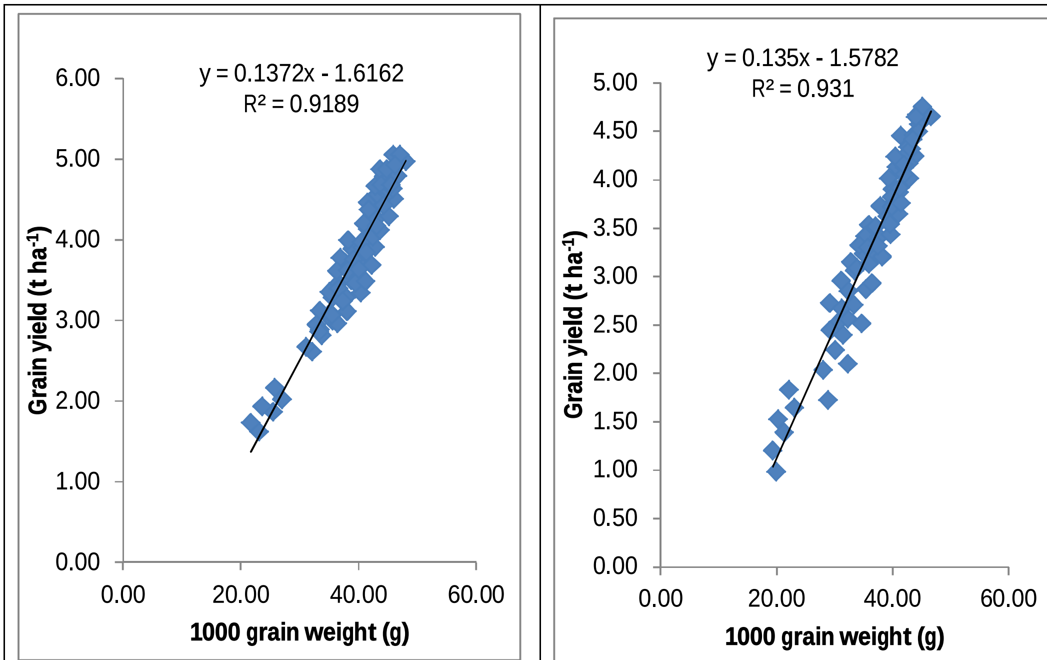


Figure 42: Correlation between 1000-grain weight and grain yield in 2015-2016 and in 2017-2018

This study investigated on late seeding heat stress condition on wheat variety and analyzed the quality or specification to help better selection of wheat variety under global climate change situation for commercial packed wheat flour for the people.

Two released wheat varieties were taken for the determination of chemical characteristics. The seeds were stored under a suitable storage condition. The nutrient compositions of wheat grains are reported.

4.4 Physiochemical parameters

The proximate composition of the whole wheat seeds of two released variety were presented in different tables. The data mentioned were the average of three replications and had been presented and discussed.

4.4.1 Protein content of whole wheat

Protein is one of the major nutrients of whole wheat varieties. Protein content is genetically controlled. Protein content in grain was significantly influence by late seeding heat stress condition in both the years. Protein content of wheat becomes high with late seeding. The highest protein content in grain was observed in 25th December (D_3) in both the years. This was followed by 10th December (D_2) and 25th November (D_1) respectively. The lowest value was found in 25th November (D_1) in both the years. Heat stress hardly affects the protein concentration of grain in wheat reported by Lizana and Calderini (2013), but a strong correlation was observed between leaf nitrogen content and grain protein. Heat stress significantly limits starch biosynthesis in grains of wheat but caused a remarkable increase in total soluble sugar and protein (Sumesh *et al.* 2008 and Asthir and Bhatia 2014).

The results showed that protein content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) (10.099g and 10.576g) and the lowest was in BARI Gom 26 (V_1) (10.005g and 10.48g). These values were supported to the work of Ahmad *et al.* (2005) who studied that wheat flour contains 10.32% to 11.58% proteins. This variation it may be due to genetic makeup and on external factors associated with the crop (Shahedur *et al,* 2011).

Micro-nutrients levels had significant effect on protein content in grain in both the years. Significantly the highest protein content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b). Gulzar *et al*. (2010) reported that different wheat varieties contained 10.30 to 11.72% crude Protein. This difference might be due to the fertilizer application, ecology and agronomic practices.

The interaction effect of late seeding and variety was found to be significant in respect of protein content in grain in 2nd year. The highest protein content in grain was recorded in D_3V_2 treatment combination and lowest was found in D_1V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on protein content in grain in both the trials. D_3M_3 treatment combination gave the highest protein content in grain in both the trials. The lowest value was found in D_1M_0 treatment combination in both the trials (Table 14a and 14b).

Protein content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest protein content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.2 Carbohydrate content of whole wheat

Carbohydrate content in grain was significantly influence by late seeding heat stress condition in both the years. The highest carbohydrate content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years. Agronomic practices, environmental factors as well as variation among the varieties might be influenced the carbohydrate contents. These present result were more and less similar with the result reported by Singh *et al.* (2006), Nitika *et al.* (2008) and Rahman and Kader (2011).

Carbohydrate content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) (66.255g and 63.388g) and the lowest was in BARI Gom 26 (V_1) (65.909g and 63.09g).

Micro-nutrients levels had significant effect on carbohydrate content in grain in both the years. Significantly the highest carbohydrate content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of carbohydrate content in grain in both the years. The highest Carbohydrate content in grain was recorded in D_1V_2 treatment combination and lowest was found in D_3V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on carbohydrate content in grain in both the trials. D_1M_3 treatment combination gave the highest carbohydrate content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Carbohydrate content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest carbohydrate content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.3 Starch content of whole wheat

Starch content in grain was significantly influence by late seeding heat stress condition in both the years. The highest starch content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

Starch content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1). This result was supported the studied of Kumar *et al.* (2011) who reported the starch content in wheat flour was 76.2% and Belderok *et al.* (2000) who observed the amount of starch in wheat grain ranged 60% to 75%.

Micro-nutrients levels had significant effect on starch content in grain in both the years. Significantly the highest starch content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of starch content in grain in both the years. The highest starch content in grain was recorded in D_1V_2 treatment combination and lowest was found in D_3V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on starch content in grain in both the trials. D_1M_3 treatment combination gave the highest starch content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Starch content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest starch content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.4 p^H content of whole wheat

p^H content in grain was significantly influence by late seeding heat stress condition in both the years. The highest p^H content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

p^H content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1).

Micronutrient levels had significant effect on p^H content in grain in both the years. Significantly the highest p^H content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of p^H content in grain in 2nd years. The highest p^H content in grain was recorded in D_1V_2 treatment combination and lowest was found in D_3V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on p^H content in grain in both the trials. D_1M_3 treatment combination gave the highest p^H content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

p^H content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest p^H content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.5 TSS content of whole wheat

TSS content in grain was significantly influence by late seeding heat stress condition in both the years. The highest TSS content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

TSS content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 26 (V_1) and the lowest was in BARI Gom 28 (V_2).

Micro-nutrients levels had significant effect on TSS content in grain in both the years. Significantly the highest TSS content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of TSS content in grain in both the years. The highest TSS content in grain was recorded in D_1V_1 treatment combination and lowest was found in D_3V_2 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on TSS content in grain in both the trials. D_1M_3 treatment combination gave the highest TSS content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

TSS content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest TSS content in grain was observed in V_1M_3 treatment combination and the lowest was found in V_2M_0 treatment combination (Table 15a and 15b).

4.4.6 Ash content of whole wheat

Ash content in grain was significantly influence by late seeding heat stress condition in both the years. The highest ash content in grain was observed in 25^{th} December (D_3) in both the years. The lowest value was found in 25^{th} November (D_1) in both the years.

Ash content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1). This result was similar to work of Ahmad *et al.* (2005) who reported ash content in wheat flour 0.52-0.68%. The high level of ash is generally associated with the addition of bran in the wheat (Ali Aydin *et al.* 2009).

The present result was more or less similar with the reported value of Khan and Zeb (2007).They also reported that it contains 1.44 to 2.10% ash.

Micro-nutrients levels had significant effect on ash content in grain in both the years. Significantly the highest ash content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1})

(M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of ash content in grain in 2nd years. The highest ash content in grain was recorded in D_3V_2 treatment combination and lowest was found in D_1V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on ash content in grain in both the trials. D_3M_3 treatment combination gave the highest ash content in grain in both the trials. The lowest value was found in D_1M_0 treatment combination in both the trials (Table 14a and 14b).

Ash content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest ash content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15 and 15b).

4.4.7 Calcium (Ca) content of whole wheat

Calcium (Ca) content in grain was significantly influence by late seeding heat stress condition in both the years. The highest calcium (Ca) content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

Calcium (Ca) content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1). It is well known that wheat germ contain minerals. The values were close to the Ahmed *et al.* (2013) who reported that the Ca content of wheat flour was 23 mg 100g^{-1}.

Micro-nutrients levels had significant effect on calcium (Ca) content in grain in both the years. Significantly the highest calcium (Ca) content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3)

in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of calcium (Ca) content in grain in both the years. The highest calcium (Ca) content in grain was recorded in D_1V_2 treatment combination and lowest was found in D_3V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on calcium (Ca) content in grain in both the trials. D_1M_3 treatment combination gave the highest calcium (Ca) content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Calcium (Ca) content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest calcium (Ca) content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.8 Phosphorus (P) content of whole wheat

Phosphorus (P) content in grain was significantly influence by late seeding heat stress condition in both the years. The highest phosphorus (P) content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

Phosphorus (P) content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 28 (V_2) and the lowest was in BARI Gom 26 (V_1).

Micro-nutrients levels had significant effect on phosphorus (P) content in grain in both the years. Significantly the highest phosphorus (P) content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of phosphorus (P) content in grain in 2nd years. The highest phosphorus (P) content in grain was recorded in D_1V_2 treatment combination and lowest was found in D_3V_1 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on phosphorus (P) content in grain in both the trials. D_1M_3 treatment combination gave the highest phosphorus (P) content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Phosphorus (P) content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest phosphorus (P) content in grain was observed in V_2M_3 treatment combination and the lowest was found in V_1M_0 treatment combination (Table 15a and 15b).

4.4.9 Iron (Fe) content of whole wheat

Iron (Fe) content in grain was significantly influence by late seeding heat stress condition in both the years. The highest iron (Fe) content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

Iron (Fe) content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 26 (V_1) and the lowest was in BARI Gom 28 (V_2).

Iron contained by whole wheat cultivars also showed a varied range. The values were more or less similar with the values reported by Qazi *et al.* (2003) but lower than the Anand *et al.*(2013). The different levels of iron in soil, fertilizer and variation among the varieties might be influenced the iron content.

Micro-nutrients levels had significant effect on iron (Fe) content in grain in both the years. Significantly the highest iron (Fe) content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of iron (Fe) content in grain in both the years. The highest iron (Fe) content in grain was recorded in D_1V_1 treatment combination and lowest was found in D_3V_2 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on Iron (Fe) content in grain in both the trials. D_1M_3 treatment combination gave the highest iron (Fe) content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Iron (Fe) content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest iron (Fe) content in grain was observed in V_1M_3 treatment combination and the lowest was found in V_2M_0 treatment combination (Table 15a and 15b).

4.4.10 Zinc (Zn) content of whole wheat

Zinc (Zn) content in grain was significantly influence by late seeding heat stress condition in both the years. The highest zinc (Zn) content in grain was observed in 25th November (D_1) in both the years. The lowest value was found in 25th December (D_3) in both the years.

Zinc (Zn) content in grain was varied significantly due to varieties in both the years. The highest value was obtained in BARI Gom 26 (V_1) and the lowest was in BARI Gom 28 (V_2). The analyzed values were found more or less similar with the values reported by Welch and Graham (2002).

Micro-nutrients levels had significant effect on zinc (Zn) content in grain in both the years. Significantly the highest zinc (Zn) content in grain was found in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the years. This was followed by Zinc (5.30 kg ha^{-1}) (M_2) and Boron (1.25 kg ha^{-1}) (M_1) respectively. The lowest value was recorded in control (M_0) in both the years (Table 13a and 13b).

The interaction effect of late seeding and variety was found to be significant in respect of zinc (Zn) content in grain in both the years. The highest zinc (Zn) content in grain was recorded in D_1V_1 treatment combination and lowest was found in D_3V_2 treatment combination in both the years (Table 12a and 12b).

The interaction of late seeding and micronutrient had significant effect on zinc (Zn) content in grain in both the trials. D_1M_3 treatment combination gave the highest zinc (Zn) content in grain in both the trials. The lowest value was found in D_3M_0 treatment combination in both the trials (Table 14a and 14b).

Zinc (Zn) content in grain was varied significantly due to the interaction of variety and micronutrient in both the years. The highest zinc (Zn) content in grain was observed in V_1M_3 treatment combination and the lowest was found in V_2M_0 treatment combination (Table 15a and 15b).

Table12a. Interaction effect of late seeding and variety on nutritional composition of wheat grain per 100g in 1st year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
D_1V_1	9.813	66.628b	58.299b	6.26	**2.74a**	1.124	23.196b	195.839	**2.246a**	**1.725a**
D_1V_2	9.899	**66.857a**	**58.568a**	**6.275**	2.65b	1.163	**23.88a**	**205.741**	2.15b	1.652b
D_2V_1	10.001	65.817d	57.599d	6.213	2.555c	1.231	22.207d	177.276	2.048c	1.616b
D_2V_2	10.103	66.356c	57.92c	6.237	2.459d	1.264	22.873c	186.121	1.95d	1.548c
D_3V_1	10.201	65.281f	56.825f	6.172	2.369e	1.332	21.16f	160.934	1.851e	1.517c
D_3V_2	**10.295**	65.554e	57.252e	6.192	2.278f	**1.363**	21.844e	168.765	1.759f	1.443d
LS	NS	0.010	0.050	NS	0.010	NS	0.010	NS	0.010	0.010
CV	4.40	4.12	4.22	4.11	4.91	5.52	5.00	5.99	5.74	5.99

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Table 12b. Interaction effect of late seeding and variety on nutritional composition of wheat grain per 100g in 2nd year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
D_1V_1	10.29f	63.792a	56.746b	6.158ab	**2.918a**	1.309c	21.054b	228.897b	**1.965a**	**1.886a**
D_1V_2	10.378e	**63.932a**	**56.918a**	**6.175a**	2.854a	1.349c	**21.405a**	**236.137a**	1.86b	1.843b
D_2V_1	10.474d	62.999c	55.916d	6.117bcd	2.752b	1.422b	20.09d	207.446d	1.775c	1.784c
D_2V_2	10.579c	63.508b	56.403c	6.136abc	2.666c	1.458b	20.356c	217.524c	1.683d	1.733d
D_3V_1	10.675b	62.481e	55.377f	6.076d	2.558d	1.526a	19.033f	190.241f	1.589e	1.681e
D_3V_2	**10.771a**	62.723d	55.608e	6.095cd	2.459e	**1.561a**	19.318e	198.196e	1.486f	1.639f
LS	0.050	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.050
CV	4.40	4.12	4.20	4.11	4.77	5.09	5.05	5.62	5.71	5.19

Table 13a. Effect of micronutrient on nutritional composition of wheat grain per 100g in 1st year

Parameter / Micronutrient	Protein (g)	Carbohydrate (g)	Starch (g)	pH	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
M_0	8.798d	60.887c	52.752d	5.836c	1.54d	0.737d	17.109d	88.076d	1.01d	1.061d
M_1	9.803c	65.332b	56.969c	6.194b	2.206c	1.1c	21.122c	152.209c	1.704c	1.446c
M_2	10.422b	67.501b	59.213b	6.332ab	2.816b	1.416b	24.288b	212.786b	2.327b	1.745b
M_3	**11.186a**	**70.607a**	**62.041a**	**6.538a**	**3.471a**	**1.733a**	**27.588a**	**276.712a**	**2.962a**	**2.083a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.22	4.11	4.91	5.52	5.00	5.99	5.74	5.99

Table 13b. Effect of micronutrient on nutritional composition of wheat grain per 100g in 2nd year

Parameter / Micronutrient	Protein (g)	Carbohydrate (g)	Starch (g)	pH	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
M_0	9.256d	58.139c	51.24d	5.745c	1.735d	0.924d	14.927d	115.244d	0.783d	1.234d
M_1	10.279c	62.472b	55.396c	6.092b	2.409c	1.294c	18.724c	182.842c	1.416c	1.622c
M_2	10.901b	64.671b	57.546b	6.234ab	3.000b	1.603b	21.872b	244.855b	2.038b	1.923b
M_3	**11.676a**	**67.675a**	**60.463a**	**6.433a**	**3.660a**	**1.928a**	**25.314a**	**309.352a**	**2.668a**	**2.265a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.20	4.11	4.77	5.09	5.05	5.62	5.71	5.19

Table 14a. Interaction effect of late seeding and micronutrient on nutritional composition of wheat grain per 100g in 1st year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	pH	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
D_1M_0	8.602h	61.648efg	53.518def	5.89bcd	1.684j	0.631h	18.165i	101.345j	1.201j	1.171i
D_1M_1	9.608fg	66.036b-e	57.664bc	6.238abc	2.41g	1.004f	22.199fg	172.304g	1.913g	1.539fg
D_1M_2	10.223def	68.113a-d	59.892abc	6.365a	3.016d	1.304e	25.222cd	232.806d	2.519d	1.853cd
D_1M_3	10.993abc	**71.173a**	**62.66a**	**6.576a**	**3.669a**	1.635bc	**28.566a**	**296.705a**	**3.159a**	**2.192a**
D_2M_0	8.792h	60.888fg	52.723ef	5.831cd	1.539jk	0.741gh	17.135ij	86.221jk	0.998k	1.059ij
D_2M_1	9.799ef	65.273c-f	56.968cd	6.193a-d	2.202h	1.091f	21.073gh	151.269h	1.699h	1.45gh
D_2M_2	10.435cde	67.544a-d	59.228abc	6.336a	2.813e	1.418d	24.326de	212.69e	2.33e	1.743de
D_2M_3	11.183ab	70.641ab	62.118a	6.541a	3.473b	1.74ab	27.625ab	276.613b	2.968b	2.076ab
D_3M_0	8.999gh	60.127g	52.014f	5.788d	1.397k	0.838g	16.026j	76.663k	0.83k	0.953j
D_3M_1	10.001def	64.689d-g	56.275cde	6.151a-d	2.006i	1.204e	20.094h	133.055i	1.499i	1.349h
D_3M_2	10.609bcd	66.847a-d	58.521abc	6.294ab	2.62f	1.526cd	23.315ef	192.862f	2.131f	1.64ef
D_3M_3	**11.383a**	70.006abc	61.346ab	6.496a	3.271c	**1.823a**	26.572bc	256.819c	2.761c	1.979bc
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.22	4.11	4.91	5.52	5.00	5.99	5.74	5.99

Table 14b. Interaction effect of late seeding and micronutrient on nutritional composition of wheat grain per 100g in 2nd year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
D_1M_0	9.061g	58.854def	51.919efg	5.797bc	1.875g	0.817h	15.978i	130.653h	0.932j	1.341i
D_1M_1	10.084ef	63.137bcd	56.093cd	6.131abc	2.622d	1.179f	19.898fg	204.861e	1.624g	1.719fg
D_1M_2	10.7cde	65.263abc	58.24a-d	6.272a	3.195c	1.486d	22.721cd	264.163c	2.234d	2.036cd
D_1M_3	11.491ab	**68.192a**	**61.076a**	**6.467a**	**3.853a**	1.832b	**26.319a**	**330.391a**	**2.86a**	**2.363a**
D_2M_0	9.247g	58.138ef	51.236fg	5.744c	1.746 gh	0.93g	15.024ij	115.972hi	0.796j	1.24ij
D_2M_1	10.275de	62.45cde	55.367de	6.087abc	2.413e	1.298e	18.497gh	182.123f	1.398h	1.621gh
D_2M_2	10.916bcd	64.735abc	57.61a-d	6.24a	3.016c	1.606c	21.985de	244.209d	2.045e	1.912de
D_2M_3	11.668ab	67.691a	60.425ab	6.435a	3.661ab	1.926ab	25.387ab	307.635b	2.676b	2.262ab
D_3M_0	9.46fg	57.424f	50.566g	5.695c	1.586h	1.025g	13.778j	99.108i	0.621k	1.121j
D_3M_1	10.477cde	61.828cde	54.728def	6.058abc	2.192f	1.406de	17.777h	161.543g	1.226i	1.527h
D_3M_2	11.086bc	64.014abc	56.789bcd	6.191ab	2.79d	1.717c	20.91ef	226.192d	1.834f	1.821ef
D_3M_3	**11.869a**	67.142ab	59.886abc	6.398a	3.467b	**2.027a**	24.235bc	290.031b	2.469c	2.17bc
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.20	4.11	4.77	5.09	5.05	5.62	5.71	5.19

Table 15a. Interaction effect of variety and micronutrient on nutritional composition of wheat grain per 100g in 1st year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
V_1M_0	8.757e	60.696c	52.572c	5.828c	1.578d	0.716d	16.749d	84.844d	1.049d	1.101d
V_1M_1	9.752d	65.168b	56.784b	6.183b	2.259c	1.086c	20.754c	147.327c	1.759c	1.474c
V_1M_2	10.373bc	67.354ab	59.057ab	6.324ab	2.866b	1.398b	23.976b	207.98b	2.379b	1.782b
V_1M_3	11.139a	70.415a	61.884a	6.526ab	**3.515a**	1.715a	27.271a	271.915a	**3.005a**	**2.121a**
V_2M_0	8.838e	61.079c	52.931c	5.845c	1.502d	0.757d	17.468d	91.309d	0.97d	1.021d
V_2M_1	9.853cd	65.496b	57.155b	6.205ab	2.153c	1.113c	21.49c	157.091c	1.648c	1.418c
V_2M_2	10.472b	67.648ab	59.37ab	6.339ab	2.767b	1.433b	24.599b	217.592b	2.274b	1.709b
V_2M_3	**11.234a**	**70.799a**	**62.198a**	**6.55a**	3.427a	**1.751a**	**27.904a**	**281.51a**	2.92a	2.044a
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.22	4.11	4.91	5.52	5.00	5.99	5.74	5.99

Table 15b. Interaction effect of variety and micronutrient on nutritional composition of wheat grain per 100g in 2nd year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
V_1M_0	9.214e	57.963c	51.079c	5.736c	1.77d	0.907d	14.807d	111.748d	0.831d	1.256d
V_1M_1	10.229d	62.34b	55.262b	6.084b	2.452c	1.272c	18.566c	178.08c	1.463c	1.65c
V_1M_2	10.85bc	64.512ab	57.373ab	6.226ab	3.044b	1.587b	21.719b	240.869b	2.091b	1.944b
V_1M_3	11.628a	67.547a	60.337a	6.423ab	**3.704a**	1.91a	25.144a	304.748a	**2.719a**	**2.286a**
V_2M_0	9.298e	58.315c	51.401c	5.755c	1.7d	0.942d	15.046d	118.741d	0.735d	1.212d
V_2M_1	10.329cd	62.604b	55.531b	6.1ab	2.366c	1.316c	18.883c	187.604c	1.369c	1.595c
V_2M_2	10.951b	64.83ab	57.719ab	6.242ab	2.957b	1.619b	22.026b	248.84b	1.985b	1.902b
V_2M_3	**11.725a**	**67.803a**	**60.588a**	**6.444a**	3.616a	**1.946a**	**25.484a**	**313.956a**	2.617a	2.244a
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.20	4.11	4.77	5.09	5.05	5.62	5.71	5.19

Table 16a. Interaction effect of late seeding, variety and micronutrient on nutritional composition of wheat grain per 100g in 1st year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
$D_1V_1M_0$	8.559 k	61.561bcd	53.423d-h	5.882c-f	1.726 op	0.612 l	17.851k-n	95.752rs	1.239qr	1.214lmn
$D_1V_1M_1$	9.562g-k	65.929a-d	57.483a-h	6.228a-f	2.462jkl	0.986ij	21.782ghi	167.219lmn	1.963klm	1.558hij
$D_1V_1M_2$	10.169c-g	68.012ab	59.764abc	6.361a-f	3.064def	1.281fg	24.952c-f	228.748fgh	2.576efg	1.888c-f
$D_1V_1M_3$	10.962a-f	71.009 a	62.524 a	6.568ab	**3.708 a**	1.616 cd	28.2ab	291.638ab	**3.205 a**	**2.242 a**
$D_1V_2M_0$	8.644jk	61.735bcd	53.612c-h	5.899b-f	1.643pq	0.65 l	18.478j-m	106.937qr	1.163rs	1.128mno
$D_1V_2M_1$	9.653g-k	66.143a-d	57.846a-h	6.248a-f	2.358klm	1.022 i	22.616fgh	177.389klm	1.863lmn	1.519ijk
$D_1V_2M_2$	10.277b-g	68.214ab	60.02ab	6.369a-f	2.968efg	1.327fg	25.493b-e	236.865efg	2.461fgh	1.819d-g
$D_1V_2M_3$	11.024a-e	**71.337 a**	**62.796 a**	**6.584 a**	3.63 a	1.655bcd	**28.932 a**	**301.772 a**	3.113ab	2.143ab
$D_2V_1M_0$	8.743jk	60.468 cd	52.584fgh	5.82ef	1.58pq	0.717 kl	16.74mn	83.693rs	1.044rst	1.092mno
$D_2V_1M_1$	9.735g-j	65.001a-d	56.783a-h	6.179a-f	2.241 lm	1.08 hi	20.735hij	146.881nop	1.75mno	1.481ijk
$D_2V_1M_2$	10.412a-g	67.366abc	59.092a-e	6.326a-f	2.87fgh	1.405ef	24.035d-g	206.687hij	2.385ghi	1.78e-h
$D_2V_1M_3$	11.115a-d	70.433 a	61.936ab	6.528abc	3.528ab	1.721abc	27.318abc	271.843bcd	3.012abc	2.111abc
$D_2V_2M_0$	8.841ijk	61.307bcd	52.862e-h	5.841def	1.498pq	0.765 kl	17.53lmn	88.748rs	0.952st	1.027 no
$D_2V_2M_1$	9.863f-i	65.545a-d	57.153a-h	6.207a-f	2.163mn	1.101 hi	21.411ghi	155.657mno	1.647nop	1.42jkl
$D_2V_2M_2$	10.458a-g	67.721ab	59.363a-d	6.345a-f	2.756ghi	1.431ef	24.617c-f	218.693ghi	2.276hij	1.705f-i
$D_2V_2M_3$	11.251abc	70.85 a	62.299ab	6.554abc	3.418abc	1.759abc	27.933ab	281.384abc	2.923bcd	2.042a-d
$D_3V_1M_0$	8.969h-k	60.059 d	51.71 h	5.781 f	1.428 q	0.82 k	15.655 n	75.086 s	0.865 t	0.998 no
$D_3V_1M_1$	9.96e-h	64.576a-d	56.085b-h	6.142a-f	2.074mn	1.192gh	19.745i-l	127.883pq	1.565 op	1.382jkl
$D_3V_1M_2$	10.537a-g	66.685a-d	58.314a-g	6.285a-f	2.663hij	1.509 de	22.943e-h	188.504jkl	2.176ijk	1.677f-i
$D_3V_1M_3$	11.34ab	69.803 a	61.192ab	6.481a-e	3.309bcd	1.808ab	26.296a-d	252.264def	2.798cde	2.01b-e
$D_3V_2M_0$	9.03h-k	60.195 d	52.317gh	5.796 f	1.366 q	0.857jk	16.397mn	78.24 s	0.795 t	0.908 o
$D_3V_2M_1$	10.042d-h	64.802a-d	56.465a-h	6.16a-f	1.937 no	1.217gh	20.444h-k	138.227 op	1.433pq	1.315klm
$D_3V_2M_2$	10.682a-g	67.009a-d	58.727a-f	6.304a-f	2.576ijk	1.542 de	23.687d-g	197.219ijk	2.085jkl	1.602g-j
$D_3V_2M_3$	**11.427 a**	70.209 a	61.499ab	6.51a-d	3.232cde	**1.838 a**	26.848abc	261.374cde	2.724def	1.948b-e
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.22	4.11	4.91	5.52	5.00	5.99	5.74	5.99

Table 16b. Interaction effect of late seeding, variety and micronutrient on nutritional composition of wheat grain per 100g in 2nd year

Parameter / Interaction	Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (%)	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
$D_1V_1M_0$	9.019 k	58.793 b-e	51.784 c-f	5.786 b-e	1.904 lm	0.794 o	15.857 lm	127.125 op	0.981pq	1.36mno
$D_1V_1M_1$	10.038 e-k	63.043 a-e	55.996 a-f	6.121 a-e	2.662 g-j	1.159klm	19.652 g-j	200.764ijk	1.666jkl	1.744g-k
$D_1V_1M_2$	10.647 b-f	65.207ab	58.183ab	6.266 a-e	3.219 de	1.468 f-i	22.544 c-f	260.626efg	2.283ef	2.057cde
$D_1V_1M_3$	11.458 a-d	68.124 a	61.021 a	6.461 a	**3.886 a**	1.813 cd	26.16 a	327.073ab	**2.929 a**	**2.386 a**
$D_1V_2M_0$	9.103jk	58.916 b-e	52.053 c-f	5.808 a-e	1.846lmn	0.841 o	16.099klm	134.181 no	0.883qr	1.322 no
$D_1V_2M_1$	10.129 e-k	63.231 a-e	56.19 a-f	6.142 a-e	2.582hij	1.198 kl	20.145 f-j	208.957ij	1.583klm	1.694h-l
$D_1V_2M_2$	10.754 a-e	65.32ab	58.297ab	6.278 a-e	3.171 de	1.505fgh	22.898 b-e	267.7def	2.186fg	2.016def
$D_1V_2M_3$	11.525 a-d	**68.259 a**	**61.131 a**	**6.473 a**	3.819ab	1.851bcd	**26.478 a**	**333.71 a**	2.79ab	2.34ab
$D_2V_1M_0$	9.195ijk	57.723cde	50.951ef	5.733 de	1.78mn	0.912 no	14.922 m	113.077opq	0.835qr	1.263 op
$D_2V_1M_1$	10.211 e-j	62.241 a-e	55.118 a-f	6.079 a-e	2.457ijk	1.278jk	18.415ijk	176.157klm	1.441lmn	1.652i-l
$D_2V_1M_2$	10.89 a-e	64.492abc	57.327 a-d	6.231 a-e	3.073ef	1.589efg	21.805 d-g	238.365gh	2.1fgh	1.936efg
$D_2V_1M_3$	11.602abc	67.538 a	60.268ab	6.426ab	3.698abc	1.907abc	25.219ab	302.187bc	2.725abc	2.286ab
$D_2V_2M_0$	9.3 h-k	58.553 b-e	51.521def	5.755cde	1.711mn	0.948 no	15.125 m	118.868opq	0.758qrs	1.216 op
$D_2V_2M_1$	10.339 d-i	62.659 a-e	55.616 a-f	6.094 a-e	2.368jk	1.318ijk	18.579hij	188.088jkl	1.355mno	1.589jkl
$D_2V_2M_2$	10.942 a-e	64.977ab	57.893abc	6.248 a-e	2.96efg	1.622ef	22.164 c-g	250.054fgh	1.991ghi	1.887e-h
$D_2V_2M_3$	11.735ab	67.844 a	60.583ab	6.444ab	3.624abc	1.945abc	25.554 a	313.084abc	2.628bcd	2.238abc
$D_3V_1M_0$	9.428 g-k	57.372 e	50.503 f	5.688 e	1.627mn	1.014mn	13.643 m	95.042 q	0.678rs	1.145 op
$D_3V_1M_1$	10.436 c-h	61.735 a-e	54.671 b-f	6.052 a-e	2.236 k	1.38hij	17.63jkl	157.319mn	1.284 no	1.554klm
$D_3V_1M_2$	11.013 a-e	63.836 a-e	56.609 a-f	6.182 a-e	2.84fgh	1.702 de	20.806 e-i	223.618 hi	1.889hij	1.839f-i
$D_3V_1M_3$	11.824ab	66.979 a	59.723ab	6.381 a-d	3.528bc	2.009ab	24.052 a-d	284.985cde	2.503cde	2.186a-d
$D_3V_2M_0$	9.492 f-k	57.477 de	50.628 f	5.702 e	1.544 n	1.037lmn	13.914 m	103.174pq	0.563 s	1.097 p
$D_3V_2M_1$	10.518 c-g	61.921 a-e	54.786 b-f	6.064 a-e	2.147 kl	1.432 g-j	17.925jkl	165.767 lm	1.168 op	1.501lmn
$D_3V_2M_2$	11.159 a-e	64.192 a-d	56.968 a-e	6.199 a-e	2.739ghi	1.731 de	21.015 e-h	228.765 hi	1.778ijk	1.804f-j
$D_3V_2M_3$	**11.914 a**	67.304 a	60.05ab	6.414abc	3.406 cd	**2.044 a**	24.418abc	295.076 cd	2.434 de	2.155bcd
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.40	4.12	4.20	4.11	4.77	5.09	5.05	5.62	5.71	5.19

CHAPTER 5

DISCUSSION

CHAPTER 5
DISCUSSION

Wheat is the second important crop in the world, whose research in this feature of importance for food quality, safety and yield in the field. Reduced plant growth is a common phenomenon when grown under increased heat stress.

This chapter deals with the discussion of results of the experiments with relation to crop growth, yield and yield components and nutritional quality of wheat as influenced by late seeding heat stress condition, variety and application of different levels of micronutrients.

The result of the present investigation revealed that 2 variety of wheat cultivar was sown in 1 optimum and 2 late seeding dates affected by the application of 4 micronutrients levels during the period from 2015 to 2016 and 2017 to 2018. Of them, high yielding and heat tolerant variety like BARI Gom 26 (V_1) and BARI Gom 28 (V_2) were selected. This 2 varieties were sown in 1 optimum date i.e., 25th November (D_1) and later on 10th December (D_2) and 25th December (D_3) in late seeding heat stress condition. In this study, heat stress decreased grain yields of BARI Gom 26 (V_1) and BARI Gom 28 (V_2). On the other hand, 4 micronutrient levels such as control (M_0), Boron (1.25 kg ha^{-1}) (M_1), Zinc (5.30 kg ha^{-1}) (M_2) and combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) were applied. Application of different levels of micronutrient at different growth stages resulted in a significant increase in growth and yield of both varieties over control (M_0).

From the majority of growth, yield and yield components and nutritional quality of wheat parameters the maximum values were obtained in BARI

Gom 28 (V_2) sown in optimum date 25th November (D_1) with the application of combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in both the experimental years.

In the present study more or less similar phenological observations were recorded in both the years.

Growth parameters

TDM

Total dry matter variation was slow at the early stages of plant growth and widens at later growth stages in both the years. Total dry matter increased with the advancement of plant age. Talukder (1987), Balyan *et al.* (1992), Rahman *et al.* (2006), Roy and Gallagher (1989) and Rahman (2004) were reported the cause of rapid increase of TDM at later stages was possibly due to the emergence of considerable number of new tillers $plant^{-1}$ and fertile spike $plant^{-1}$.

The result of the present investigation revealed that TDM production was significantly higher in the optimum date of sowing date than the late seeding and it may be due to proper utilization of' CO_2 and solar radiation. TDM decreased with the late seeding heat stress condition and this might be due to the heat stress on wheat plants. 25th November produced highest TDM.

TDM varied significantly due to variety in both the years. The highest TDM was produced by BARI Gom 28 (V_2). It might be due to the reason of genetic characteristics, environmental factors and origin.

There was significant effect of micronutrients on TDM in both the years. Significantly the highest TDM was found in combination of B 1.25 kg ha^{-1} and Zn 5.30 kg ha^{-1} (M_3) than other treatments. This might be due to steady availability of nutrition during growth. Control (M_0) treatment showed the lowest TDM value at all the growth stages of wheat in both the years. This might be due to lack of nutrition in crop.

The interaction effect of variety and micronutrients on TDM was significant in both the years. V_2M_3 treatment combination gave the highest TDM in both the years.

LAI

In the present investigation, leaf area index (LAI) increased with the progress towards the growth period and peak value was reached at Anthesis stage. Then it decreased gradually at the later stages of plant growth. The value of LAI was higher in the optimum sowing date than the late seeding at all the growth stages. Day and night temperature around 30 and 25°C, respectively, may have severe effects on leaf development and productive tiller formation in wheat (Rahman *et al.* 2009).

25th November showed the highest LAI. This might be due to the increase of leaf expansion for the optimum light, water and nutrient which also facilitated the crop for absorption of greater amount of nutrients, moisture and greater reception of solar radiation that for better growth and development of crop. Soil moisture increased relative leaf water content which increased cell expansion and ultimately leaf area was increased. Heat stress may occur due to late seeding. However, Zhao *et al.* (2007) showed that a large diurnal variation in temperature is also responsible for the promotion of flag leaf senescence in wheat.

A significant variation was observed in respect of leaf area index among the varieties. The maximum value for LAI was observed for variety BARI Gom 28 (V_2), in both the experimental years at Anthesis stage. This is due to varietal potentiality as BARI Gom 28 (V_2) produced the highest LAI between two varieties.

Significantly the highest LAI was found at the combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). There was a general trend of declining LAI as the age of the plant advanced. LAI was higher at Anthesis stage and then declined up to Physiological maturity stage. This was because it was the changeover period from vegetative to reproductive phase. This might be due to the effect of application of micronutrient that contributed to the increased number of leaves per unit area resulting in increased leaf area.

CGR

Photosynthesis is the most sensitive physiological event leading to poor growth performance in wheat (Feng *et al*. 2014). CGR decreased with the late seeding heat stress condition at tillering and booting stage in wheat variety. This might be due to critical environmental condition during growth period. At tillering and booting stage three seeding date produced significantly highest CGR in both the years. Higher CGR in the optimum sowing date was due to the higher production of dry matter.

BARI Gom 28 (V_2) produced the highest CGR values in all the sampling stage. Crop growth rate increased slowly at early stages of growth and reached the peak at booting to heading stage in 1st year and heading to anthesis stage in 2nd year thereafter it declined. This was might be due to the maximum production of dry matter at early stages of plant growth. The net result of photosynthesis, respiration and canopy area interaction rate are represented by crop growth.

There was an increasing trend of crop growth rate with the application of micronutrients. The highest crop growth rate was noted at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3).

BARI Gom 28 (V_2) produced the highest CGR at highest level of micronutrient application with combination of (B 1.25 kg ha^{-1}+Zn 5.30

kg ha^{-1}) as less competition among the plants for solar radiation, air and thereby assimilation of CO_2 by the green tissues was higher.

RGR

There was a significant effect of sowing date on relative growth rate in both the seasons. The maximum relative growth rate values was recorded from BARI Gom 28 (V_2) in 25th November (D_1) at tillering to booting stage and the minimum one was obtained from BARI Gom 26 (V_1) in 25th December (D_3).

Higher relative growth rate was noticed at early stages of growth in both the varieties in both the years. These results are in agreement with the findings of El-Shear *et al.* (1979), Khan (1979) and Rahman (2004) in wheat. Relative growth rate values decreased steadily with the increasing of age of the plant due to less dry matter accumulation. BARI Gom 26 (V_1) gave the highest relative growth rate values in 1st year and BARI Gom 28 (V_2) gave in 2nd year with a few exceptions.

At crown root initiation to tillering and tillering to booting stage relative growth rate become high in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment in comparison with other treatments. It was due to higher response of micronutrients to the crop and more dry matter production.

NAR

Net assimilation rate (NAR) measured the amount of dry matter production per unit area of leaf surface and it is an indicator of photosynthetic efficiency. It was observed that NAR getting higher during vegetative phase and decline rapidly as growth progressed (Koller *et al.* 1970, Padmaja *et al.* 2003, Ahmed *et al.* 2000, Han *et al.* 2005). This might be due to mutual shading of leaf and increased number of aged leaves which lost photosynthetic efficiency (Pandey *et al.* 1978).

Sowing date had significant effect on NAR. The highest net assimilation rate was found in plants sown in 25th November (D_1) and lowest value in 25th December (D_3) in both experimental years at tillering to booting stage.

The highest net assimilation rate was noticed from variety BARI Gom 26 (V_1) in all growth stages in 1st year except at tillering to booting stage and booting to heading stage and BARI Gom 28 (V_2) in 2nd year except CRI to tillering stage.

With a few exceptions, it was observed that combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment showed highest NAR and control (M_0) treatment showed the lowest NAR in both the years.

Net assimilation rate (NAR) values showed heavy fluctuation throughout the plant growth period in all the sowing date with both the cultivars and application of micronutrient. NAR values increased up to booting to heading stage and then decreased in both the cultivars.

LAR

In the present study the highest leaf area ratio was noticed in optimum sowing date 25th November (D_1) at crown root initiation to tillering stages and the lowest was recorded in late seeding date 25th December (D_3) both the years. A major effect of heat stress is the reduction in photosynthesis resulting from decreased leaf area expansion, impaired photosynthetic machinery, premature leaf senescence, and associated reduction in wheat production was reported by Ashraf and Harris (2013).

Leaf area ratio values under different varieties were found high at crown root to tillering stage and then decreased gradually with the advancement of plant growth. The maximum leaf area ratio was noted from BARI Gom 26 (V_1) at all the stages except CRI to tillering stage in both the experimental years. This is might be due to maximum leaf area than rest of the varieties studied. Leaf area ratio increased more or less with the increase of micronutrient application. This result was observed as micronutrient induces better plant growth and sustains physiological functions.

Yield and yield contributing character

Plant height

Plant height is dependent on the number of internodes and their length. Significantly the tallest plant height was obtained from 25th November (D_1) compared to late seeding in both the years. Heat treatment on ggrowth stages has major effects, 45°C, 2 h After 7 days of germination reduced length and dry mass of shoot and root; decreased chlorophyll and membrane stability index Gupta *et al.* (2013a).

Plant height increased rapidly with the progress towards the growth period in all the treatments of both the cultivars and years. BARI Gom 26 (V_1) produced the tallest plant in both the experimental years.

Micronutrient level had significant effect on plant height. Plant highest increased with increasing levels of micronutrient application. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produced the longer plant in both the years. On the other hand control (M_0) treatment showed the lowest plant height in both the years.

The tallest plant was noticed from D_1V_2, D_1M_3 and V_2M_3 treatment combinations in both the years. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) showed the highest plant height and it was followed by optimum sowing date 25th November (D_1) in BARI Gom 28 (V_2) both the years.

Number of total tillers plant^{-1}

Heat stress may affect every stage of plant growth and physiology, especially the reproductive phase. Late seeding date 25th December (D_3) produced the highest number of total tillers plant^{-1}. Heat stress increases the number of tillers plant^{-1}.

In this experiment BARI Gom 26 (V_1) produced higher number of tillers plant^{-1} in both the cropping years. This might be due to varietal potentiality as BARI Gom 26 (V_1) produced the higher number of tillers plant^{-1}.

Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) showed the highest number of total tillers plant^{-1} in both the years. Micronutrient encourages tiller production and for this reason number of tillers plant^{-1} increased with the combination of boron and zinc fertilizer.

The treatment combination of D_3V_1, D_3M_3 and V_1M_3 produced significantly highest number of total tillers plant^{-1}. Maximum number of tillers plant^{-1} was noted in 25th December (D_3) and minimum one in 25th November (D_1). This is might be due to varietal capability of BARI Gom 26 (V_1) and thereby produces maximum tillers plant^{-1} with more combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) uptake.

Number of effective tillers plant^{-1}

Sowing date had significant effect on number of effective tillers plant^{-1}. Result revealed that the highest number of effective tillers plant^{-1} was obtained from optimum sowing date 25th November (D_1) and lowest was in late seeding 25th December (D_3) in both the years.

The highest effective tillers plant^{-1} was noted in BARI Gom 28 (V_2). The reasons of differences in producing effective tillers plant^{-1} might be due to genetic make-up of the varieties primarily influenced by heredity.

Result showed that application of micronutrient is considered better than control (M_0) treatment increasing number of effective tillers plant^{-1}. Significant the highest number of effective tillers plant^{-1} was observed in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and lowest was in control (M_0). Micronutrient application encouraged effective tillers production and for that reason effective tillers increased with the increase of combination of B and Zn.

Treatment combinations of D_1V_2, D_1M_3 and V_2M_3 produced higher number of effective tillers plant^{-1}. The highest number of effective tillers plant^{-1} was noticed in BARI Gom 28 (V_2) in optimum sowing date at the highest level of micronutrient level.

Spikelets spike^{-1}

Optimum date of sowing is one of the most important agronomic management in agriculture. The optimum temperature for wheat anthesis and grain filling ranges from 12 to 22°C (Shewry 2009). Bennett *et al.* (2012). Number of spikelets spike^{-1} was significantly influenced by date of sowing in both the years. 25th November (D_1) produced the highest number of spikelets spike^{-1} and the lowest value was observed in 25th December (D_3).

Significantly the highest number of spikelets spike^{-1} was found in BARI Gom 28 (V_2).

Results showed that application of micronutrient is better than control (M_0) application in increasing number of spikelets spike^{-1}. Significantly the highest number of spikelets spike^{-1} was observed in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3).

Spike length

25th November (D_1) showed the highest spike length in both the years. Results showed that spike length decreased late seeding. This might be due to the steady availability of advantageous condition during growth period of crop.

Significantly the longest spike was produced by BARI Gom 28 (V_2) in both the experimental years. Result showed that spike length increased with the increase of splits application of micronutrient. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) showed significantly highest spike length in both the years. Micronutrient took part in spike formation as well as spike elongation and for this reason spike length increased.

The treatment combinations D_1V_2, D_1M_3 and V_2M_3 produced more or less statistically similar result in both years. Hedhly *et al.* (2009) reported in wheat, the anther produced under 3 days heat stress during anthesis was found to be structurally abnormal and nonfunctional florets.

Number of grains spike^{-1}

Sowing date had significant effect on grains spike^{-1} in both the years. The highest grains spike^{-1} was recorded in 25th November (D_1). However, Nawaz *et al.* (2013) observed that the prevalence of reproductive stage heat stress has been found to be more detrimental in wheat production.

Number of grains spike^{-1} varied significantly due to variety. Grain-filling stage in wheat is very sensitive to high temperature (Farooq *et al.* 2011). Heat stress generally accelerates the rate of grain-filling and shortens the grain-filling duration (Dias and Lidon 2009a).

BARI Gom 28 (V_2) produced the maximum number of grains spike^{-1} and the minimum one was produced by the variety BARI Gom 26 (V_1).

Number of grains spike^{-1} increased with application of micronutrients. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produced the highest number of grains spike^{-1}. Adequate supply of micronutrient contributed to grain formation which probably increased number of grains spike^{-1}. Micronutrient helped in proper filling of grains and produced heavy and plump seeds and thus number of grains spike^{-1} was increased. Treatment combinations of D_1V_2, D_1M_3 and V_2M_3 produced highest number of grains spike^{-1}. Heat stress adversely affects pollen cell and microspore resulting into male sterility (Anjum *et al.* 2008).

1000-grain weight

Result showed that 25th November (D_1) produced the highest 1000-grain weight in both the years. Increase in temperature of 1-2°C reduces seed mass by accelerating seed growth rate and by shortening the grain-filling periods in wheat was observed by Nahar *et al.* (2010). Yin *et al.* (2009) showed in wheat, grain-filling duration may be decreased by 12 days with the increase of 5°C temperature above 20°C.

This result indicates that proper sowing date is responsible for quality of grains and their weight. The highest 1000-grain weight was found in BARI Gom 26 (V_1) while lowest value was found in BARI Gom 28 (V_2) in both the years.

Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) showed the highest 1000-grain weight in both the years.

Grain yield

Grain yield is the ultimate goal of wheat cultivation. The optimum sowing date 25th November (D_1) produced highest grain yield. This is due to the maximum number of effective tillers plant^{-1}, highest number of grains spike^{-1} and higher 1000-grain weight. Grain yield decreased with the late seeding due to unfavorable condition for heat stress. Grain yield is associated with number of effective tillers plant^{-1}, number of fertile spikelets spike^{-1}, number of grains spike^{-1} and 1000-grain weight. Sowing wheat in optimum date increases the number of effective tillers plant^{-1}, number fertile spikelets spike^{-1}, number of grains spike^{-1} and 1000-grain weight which ultimately led to increase grain yield. The adverse effect of late sowing on wheat yield at BAU farm has also been reported in the past (Hossain *et al.* 1994). Prasad and Djanaguiraman (2014) reported plants exposed to temperatures above >24°C during reproductive stage significantly reduced grain yield and yield reduction continued with increasing duration of exposure to high temperature.

Grain yield is affected by variety in different manners. Significantly the highest grain yield was observed in BARI Gom 28 (V_2).

Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produced the highest grain yield. However some differences were noticed after flowering. The spikes in the boron untreated plots turned brownish black, and produced fewer number of grains $spike^{-1}$. The affected grains were partly blackened and shriveled. On the other hand Zinc (Zn) deficiency and heat stress also affect the wheat productivity by reducing kernel growth and chloroplast function (Peck and McDonald 2010).

Therefore, Zn and B have been proven to be effective in improving heat tolerance in wheat. Further this variety can be chosen as a breeding material in the wheat improvement program.

Treatment combination of D_1V_2, D_1M_3 and V_2M_3 produced higher grain yield. The increase in night temperature is more responsive, shortens the grain filling period, and reduces the grain yield than that of day temperature. Night temperatures of 20 and 23°C reduced the grain-filling period by 3 to 7 days (Prasad *et al.* 2008a).

Biological yield

Significantly the highest biological yield was noticed in 25^{th} November (D_1).

BARI Gom 28 (V_2) produced the highest biological yield in 25^{th} November (D_1) in both the experimental years. This is might be due to maximum expression of important yield components in optimum sowing date.

Significantly the highest biological yield was observed at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment. This is might be due to the highest micronutrient response to the crops and its use efficiency by the plants, resulting significantly the maximum number of tillers $plant^{-1}$, highest 1000-grain weight and higher number of grains $spike^{-1}$. The lowest biological yield was obtained from control (M_0) treatment due to poor tiller number, lowest spikelets $spike^{-1}$, lowest 1000-grain weight and minimum number of grains $spike^{-1}$.

BARI Gom 28 (V_2) produced the highest biological yield at the combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) in November (D_1). This is might be due to the maximum spikes $plant^{-1}$, 1000-grain weight and maximum number of effective tillers $plant^{-1}$ compared to that of control (M_0).

Biochemical Analysis

In this part of the present research genetic divergence in 2 wheat genotypes for nutritional quality characters at 3 late seeding heat stress condition with application of 4 levels of micronutrient were studied. The bran is the outer layer of whole grain which contains the largest amount of ber (insoluble), B vitamins, trace minerals and a small amount of protein; the endosperm is the middle layer which contains mostly protein and carbohydrates along with small amounts of B vitamins, iron and soluble ber; and the germ is inner part which is a rich source of trace minerals, unsaturated fats, B vitamins, antioxidants, phytochemicals and a minimal amount of high quality protein.

Different quality characters *viz.*, soluble protein (SP), carbohydrate content, starch content, pH, total soluble solids (TSS), ash, calcium

(Ca), phosphorous (P), iron (Fe) and zinc (Zn) content were determined from whole wheat after harvest. The results obtained in this part of investigation are discussed with an endeavor to justify them.

Protein content in grain

Wheat contains high quality protein. Protein exist in wheat in both soluble and insoluble forms.

The highest protein content in grain was found in late seeding date 25th December (D_3) in both the years. However, Castro *et al.* (2007) reported wheat plants experiencing heat stress early in grain filling were found to have high content of grain protein.

Significantly the highest grain protein content was found in BARI Gom 28 (V_2). The variation in the proximate composition might be due to genetic and non-genetic factors.

Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produced the highest protein content in grain. Grain protein content increased with micronutrient application. This might be due to maximum uptake of micronutrient and its use efficiency.

The treatment combinations D_3V_2, D_3M_3 and V_2M_3 showed the higher grain protein content in both the years.

Carbohydrate content of whole wheat

The highest carbohydrate content in grain was noted in 25th November (D_1) at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). This might due to more micronutrient uptake in optimum sowing date for favorable environmental condition.

The highest carbohydrate content in grain was observed in BARI Gom 28 (V_2) and the lowest one in BARI Gom 26 (V_1).

Grain carbohydrate content was highest at combination of (B 1.25 kg ha^{-1} +Zn 5.30 kg ha^{-1}) (M_3) in both the experimental years. This is due to maximum uptake of micronutrient and its use efficiency.

Starch content of whole wheat

Significant variation was noted in starch content between the 2 wheat cultivars. BARI Gom 28 (V_2) obtained highest amount starch content. Wheat grain contains 60-75% starch of its total dry weight (Sramkova *et al.* 2009). The starch content plays very vital roles in the quality of wheat products and varies with wheat cultivars.

Availability of resources during growth period has a substantial effect on grain starch content. The highest grain starch content was observed in optimum sowing date at 25th November (D_1). The grain starch content decreased with the late seeding heat stress condition. Around 97% of activity was lost due to the decrease in soluble starch syntheses at 40°C, resulting in reducing grain growth and starch accumulation in wheat was observed by Chauhan *et al.* (2011).

The highest grain starch content was observed in combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treatment and lowest value was in control (M_0) treatment. The grain starch content increased with combination of boron and zinc fertilizer application.

p^H content of whole wheat

Significant variation was observed between the varieties for p^H of wheat. p^H influences the enzyme activity in wheat grain which involves starch-sugar conversion.

The lowest p^H content in grain was noticed in 25th December (D_3) at late seeding heat stress condition. This is due to lack of favorable condition. The highest p^H content in grain was found in BARI Gom 28 (V_2). Grain p^H content is significantly influenced by different levels of micronutrient in both cropping seasons. The highest p^H content was observed at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest was recorded at control (M_0) treatment.

TSS content of whole wheat

Result showed that TSS content increased with the sowing at optimum date. 25th November (D_1) produced the highest TSS content.

Significant variation was observed between the varieties in case of total soluble solids (TSS) content in wheat grain. BARI Gom 26 (V_1) showed the better performance in respect of TSS content.

Application of micronutrient showed significant effect on TSS content. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produced the highest TSS content.

The treatment combinations of D_1V_1, D_1M_3 and V_1M_3 showed the higher TSS content.

Ash content of whole wheat

The highest ash content in grain was noticed at 25th December (D_3) might be due to ash content increase with late seeding. Significant variation in ash content in wheat variety was observed. The highest ash content in grain was noted in BARI Gom 28 (V_2) and the lowest one in BARI Gom 26 (V_1).

All the treatments on ash content in wheat grain significantly verified compared to control treatment in both experimental years. It was seen that combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) treated wheat variety grain contain highest ash. This might be due to high nutrition responses to variety and its use efficiency. The highest ash content in grain was noted in BARI Gom 28 (V_2) which was sown in 25th December (D_3).

Calcium (Ca) content of whole wheat

Significant variation in Ca content was observed between the 2 wheat varieties. Its content increased with the maturity of grain.

Wheat is a significant source of calcium (Ca), with a wide range reported. BARI Gom 28 (V_2) showed higher Ca content. The highest Ca content was recorded at the highest level of micronutrient combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). This is might be due to maximum uptake of available nutrient and accumulation of dry matter. The highest Ca content in grain was noticed in optimum sowing date 25^{th} November (D_1) at combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3). This is due to high nutrient responses by the varieties. The lowest Ca content in grain was observed in 25^{th} December (D_3) at control (M_0) treatment.

Phosphorus (P) content of whole wheat

Phosphorous is one of the main mineral present in wheat. It has role in the human body and is a key player for healthy cells, teeth and bones. Phosphorous content in wheat was found to be different in the present investigation and it increased with grain maturity.

Phosphorous content was affected significantly by sowing date in both the years. BARI Gom 28 (V_2) was sowing in optimum date treated with combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) showed the highest Phosphorous content. This may be due to the favorable condition which facilitated the crop for absorption of greater amount of plant nutrients, moisture and greater reception of solar radiation for better growth. However, late seeding date 25^{th} December (D_3) showed the lowest Phosphorous content in control (M_0) treatment.

Iron (Fe) content of whole wheat

Though iron (Fe) present fairly low amounts, it may make a contribution to dietary intake. Significant difference in Fe content was observed between two wheat varieties. Fe, in association with chlorogenic acid, causes after-cooking darkening. Of all the micronutrients, iron (Fe) is required by plants in the largest amount.

Iron (Fe) content showed significant variation due to sowing date in both the years. The highest iron (Fe) content was obtained from the optimum sowing date 25th November (D_1). There was a significant effect in respect of iron (Fe) content due to varieties. BARI Gom 26 (V_1) produced higher iron (Fe) content in both the experimental years. This is might be due to genetic potentiality of variety. Significantly the highest iron (Fe) content was found at the combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) and the lowest was found at control (M_0) treatment.

Zinc (Zn) content of whole wheat

Andre *et al.* (2007a) reported that Zinc (Zn) is an essential component of various enzyme systems for energy production and its deficiency has serious consequences for health. Significant differences in Zn content occur in wheat variety in the present investigation.

Zn content was found better when the crop was sown in 25th November (D_1). On the other hand, the Zn content went down and down when sowing was delayed from optimum date. The reduction of Zn content for late sowing was probably due to higher soil temperature during sowing to germination and that for 25th December sowing was due to shorter period at vegetative stage and rise in temperature (Appendix III) at grain filling stage.

Further idea behind this work was to see whether every variety of wheat equally responds to micronutrient and again whether the effect of micronutrient is same for all wheat cultivars sown at different dates. The result indicates that micronutrient had significant influence on Zn content. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) produce the highest Zn content.

Results of the study revealed that BARI Gom 26 (V_1) contain higher Zn between two varieties.

The overall result indicates that wheat seeds need to be sown between end of November and beginning of December and the varieties to be chosen be BARI Gom 26 (V_1) or BARI Gom 28 (V_2) for the areas under AEZ-11. Therefore, the maintaining appropriate planting time is one of the most important agronomic practices for getting optimum plant growth and yield of wheat under heat-stressed environment (Kajla *et al.* 2015). Micronutrient application is necessary for obtaining higher yield of wheat for irrespective of varieties and sowing dates.

CONCLUSION

Conclusions and future perspective in the recent past, heat stress leads enormous loss of wheat productivity worldwide. For improvement and sustenance of wheat productivity in heat stress condition, agronomic practices like micronutrient management should be practiced in different wheat variety. From the results of the present learning the following conclusions can be drawn:

Optimum sowing date showed better performance on growth, yield and grain nutrient quality of wheat. Heat stress reduces yield of wheat varieties drastically if sowing become delay. The results show that heat stress reduced growth and yield of wheat varieties. Different grain nutrient contents also decreased due to late sown heat stress condition. Among the different sowing date 25th November sowing of wheat is better than 10th and 25th December sowing in relation to the crop performance.

Based on the finding of present investigation it can be concluded that there was a wide range of variation for wheat yield and yield attributing characters among the studied varieties. The variation was due to the genetic causes. The conducted experiment revealed with a few exceptions that the variety BARI Gom 28 (V_2) gave the highest value in most of the growth stages of wheat. Nutritional quality analysis revealed that wide range of genetic variation for nutritional quality existed between the studies wheat varieties. Protein, carbohydrate, starch, p^H, ash, TSS, calcium, phosphorus, iron and zinc contents contributed towards genetic divergence. BARI Gom 28 (V_2) performed the better considering most of the nutrient contents. BARI Gom 26 (V_1) could be considered better for TSS, iron and zinc.

Exogenous application of micronutrient showed a significant increase in most of the growth, yield and grain nutritional quality of wheat. Among the different micronutrient treatments, Boron (1.25 kg ha^{-1}) (M_1) and Zinc (5.30 kg ha^{-1}) (M_2) were equally good. Combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) was adequate for growth, grain nutritional quality and higher grain yield. The overall results of the present study demonstrated that wheat may be grown successfully for obtaining maximum yield with the application of combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3)when there is heat stress occurs and situation is unfavorable as it can reduce huge yield loss.

Crop cultivation in heat stress of north-western part of Bangladesh might be profitable with micronutrient application and proper soil and water management. This is why to explore the actual effects of heat stress on final crop yield, the different biochemical and agronomic options are required.

Farmers are cultivating wheat in their field for the consumption as feed as well as public consumption. So, these traits should be considered for improvement of nutritional quality through rational selection of parental genotypes for future wheat breeding with tolerance mechanisms to heat. Based on the information mention above, it may assume that BARI Gom 26 (V_1) and BARI Gom 28 (V_2) can be cultivated in large scale because they also contain the highest amount of different nutrients content.

Based on the study results, it may be concluded here that morphological growth of wheat are positively co-related with variety, time of sowing and micronutrient application. Considering above situation, BARI Gom 26 (V_1) and BARI Gom 28 (V_2) individually may be performed the best with 25th November (D_1) sowing and micronutrient application. But under the present study, BARI Gom 28 (V_2) with 25th November (D_1) sowing and combination of (B 1.25 kg ha^{-1}+Zn 5.30 kg ha^{-1}) (M_3) was the best treatment combination for getting higher grain yield and productivity.

So, heat stress tolerance mechanism is very important for developing a prominent approach of wheat management under heat stress and forth seeing climate change settings.

However, before making conclusion concerning the appropriate dose of Zn and B, the study needs further investigation in other Agro Ecological Zones (AEZs) of Bangladesh for country-wide recommendation which will be useful. For further confirmation of the result the experiment may be conducted by including the same treatment or by manipulating the treatment combination to draw a better conclusion.

RECOMMENDATION

The following recommendations are suggested based on the data obtain from the present study:

- Further study can be established to justify the present findings. Such study is needed in different Agro-Ecological Zones (AEZ) of Bangladesh for regional adaptability and other performance of wheat variety. Some other combinations of boron (B) and zinc (Zn) with different management practices may be included for further study.
- Further analysis of different wheat varieties should be done to know their nutrients content. Nutritional analysis is also important for breeders to evolve more nutrient rich wheat variety. Chemical composition and nutritional traits suggests the future strategy for the nutritionist, health advisor and dieticians as to know how to make best use of the wheat.

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APPENDICES

APPENDICES

Appendix I. Morphological characteristics of the experimental field

Morphological features		Characteristics
1. Location	:	Regional Wheat Research Centre (RWRC), Shyampur, Rajshahi.
2. Land type	:	High land
3. General soil type	:	Calcareous dark grey soil
4. Agro-ecological zone (AEZ)	:	AEZ-11: High Ganges River Floodplain
5. Topography	:	Fairly level
6. Soil color	:	Dark grey
7. Drainage	:	Well drainage
8. Soil series	:	Gopalpur series

Appendix IIA. Chemical composition of the initial soil (0-15 cm) in 1st year

Constituent		Results*	Critical level	Interpretation
p^H	:	8.27		Alkaline
Organic matter (%)	:	1.01		Very low
Total nitrogen (%)	:	0.06	0.12	Very low
Available P (ppm)	:	9.20	10.00	Low
Available K (Cmol/Kg)	:	0.27	0.12	Medium
Available S (ppm)	:	15.07	10.00	Opt.
Available Zn (ppm)	:	0.61	0.60	Low
Available Mn (ppm)	:	-		
Available B (ppm)	:	1.04	0.20	Opt.

Source: Soil Resource Development Institute, Regional Research Station, Rajshahi

Appendix IIB. Chemical composition of the initial soil (0-15 cm) in 2nd year

Constituent		Results*	Critical level	Interpretation
pH	:	7.9		Slightly alkaline
Organic matter (%)	:	1.28		Very low
Total nitrogen (%)	:	0.07	0.12	Very low
Available P (ppm)	:	21.03	10.00	Opt.
Available K (Cmol/Kg)	:	0.31	0.12	Opt.
Available S (ppm)	:	14.07	10.00	Medium
Available Zn (ppm)	:	2.47	0.60	Medium
Available Mn (ppm)	:	-		
Available B (ppm)	:	0.98	0.20	Opt.

Source: Soil Resource Development Institute, Regional Research Station, Rajshahi.

Appendix III. Monthly air temperature, humidity and total rainfall during the study period (from November 2015 to April 2016 and from November 2017 to April 2018).

Month	Year	Air temperature (°c)	Humidity (%)	Rainfall (mm)
2015-2016				
November	2015	(High 32, Low 15) 24	79	9.4
December	2015	(High 30, Low 9) 19	80	1.5
January	2016	(High 28, Low 9) 17	82	6.2
February	2016	(High 33, Low 10) 22	75	15.8
March	2016	(High 36, Low 16) 27	64	10.6
April	2016	(High 41, Low 22) 31	68	46.7
2017-2018				
November	2017	(High 32, Low 13) 23	77	21.8
December	2017	(High 29, Low 12) 20	81	10.1
January	2018	(High 26, Low 6) 15	83	2.0
February	2018	(High 32, Low 11) 21	77	27.0
March	2018	(High 36, Low 15) 26	67	12.3
April	2018	(High 37, Low 19) 28	64	50.8

Source: Regional Meteorological Station, Shyampur, Rajshahi.

Appendix IV. Changes of phenological duration in wheat as influenced by late sowing heat stress condition

Date of sowing	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Maturity Stage
25th November	20	35	50	65	80	110
Date in Growth stages	15 Dec	30 Dec	14 Jan	29 Jan	13 Feb	16 March
10th December	20	35	55	65	75	100
Date in Growth stages	30 Dec	14 Jan	3 Feb	13 Feb	23 Feb	21 March
25th December	20	30	50	60	70	95
Date in Growth stages	14 Jan	24 Jan	13 Feb	23 Feb	6 March	1 April

Appendix VA. Simple correlation between yield and yield contributing characters of wheat as influenced by variety, sowing date and micronutrients in 1st year.

	Plant height (cm)	Total tillers $plant^{-1}$ (no.)	Effective tillers $plant^{-1}$ (no.)	Spikelets $spike^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$ (no.)	1000- grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
Plant height (cm)	1	.907**	.954**	.986**	.994**	.983**	.985**	.901**	.923**
Total tillers $plant^{-1}$ (no.)	.907**	1	.929**	.911**	.917**	.919**	.922**	.923**	.926**
Effective tillers $plant^{-1}$ (no.)	.954**	.929**	1	.964**	.965**	.978**	.977**	.982**	.992**
Spikelets $spike^{-1}$ (no.)	.986**	.911**	.964**	1	.992**	.990**	.983**	.918**	.939**
Spike length (cm)	.994**	.917**	.965**	.992**	1	.990**	.987**	.923**	.941**
Grains $spike^{-1}$ (no.)	.983**	.919**	.978**	.990**	.990**	1	.987**	.940**	.958**
1000- grain weight (g)	.985**	.922**	.977**	.983**	.987**	.987**	1	.945**	.959**
Biological yield (t ha^{-1})	.901**	.923**	.982**	.918**	.923**	.940**	.945**	1	.993**
Grain yield (t ha^{-1})	.923**	.926**	.992**	.939**	.941**	.958**	.959**	.993**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix VB. Simple correlation between yield and yield contributing characters of wheat as influenced by variety, sowing date and micronutrients in 2nd year.

	Plant height (cm)	Total tillers $plant^{-1}$ (no.)	Effective tillers $plant^{-1}$ (no.)	Spikelets $spike^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$ (no.)	1000- grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
Plant height (cm)	1	.892**	.930**	.981**	.974**	.975**	.977**	.917**	.908**
Total tillers $plant^{-1}$ (no.)	.892**	1	.922**	.920**	.902**	.915**	.921**	.917**	.894**
Effective tillers $plant^{-1}$ (no.)	.930**	.922**	1	.977**	.942**	.981**	.976**	.994**	.989**
Spikelets $spike^{-1}$ (no.)	.981**	.920**	.977**	1	.981**	.991**	.987**	.967**	.957**
Spike length (cm)	.974**	.902**	.942**	.981**	1	.965**	.967**	.937**	.921**
Grains $spike^{-1}$ (no.)	.975**	.915**	.981**	.991**	.965**	1	.992**	.968**	.971**
1000- grain weight (g)	.977**	.921**	.976**	.987**	.967**	.992**	1	.970**	.965**
Biological yield (t ha^{-1})	.917**	.917**	.994**	.967**	.937**	.968**	.970**	1	.984**
Grain yield (t ha^{-1})	.908**	.894**	.989**	.957**	.921**	.971**	.965**	.984**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix VI. Summary of analysis of variance for Total Dry Matter (g m^{-2}) at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value											
		1st year TDM (gm^{-2})						2nd year TDM (gm^{-2})					
		CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage
Replication	2	15.93	387.339	8347.375	117525.170	414580.777	440282.439	13.798	387.769	7107.042	113007.072	410446.814	514095.612
Factor (A)	2	2.506**	67.989**	33034.378**	102000.55**	242665.97**	248885.09**	3.712**	75.397**	36287.198**	114405.01**	237694.42**	233157.03**
Error	4	0.009	0.105	11.866	21.192	437.852	588.753	0.013	0.070	106.654	66.765	94.404	957.255
Factor (B)	1	0.369**	10.394**	6215.568**	23270.136**	24038.59**	26536.23**	0.790**	14.563**	6307.030**	27574.982**	71395.194**	101264.78**
Interaction (A×B)	2	0.006	0.195*	27.197**	901.021**	33.090**	133.053**	0.009	0.026**	45.979	3424.579**	79.792**	317.167**
Error	6	0.002	0.037	3.175	66.688	139.962	1711.944	0.008	0.063	14.737	93.430	426.428	383.694
Factor (C)	3	35.242**	1220.856**	437808.05**	1305243.12**	2799658.3**	3432626.51**	41.194**	1351.52**	441431.7**	1306473.9**	2948492.1**	3283547.9**
Interaction (A×C)	6	0.054**	1.293**	265.645**	282.995**	873.986**	668.719**	0.165	1.276**	511.500**	213.780**	549.993**	87.549**
Interaction (B×C)	3	0.010**	0.645**	100.295	45.673**	77.060**	612.798**	0.048**	0.026**	165.333*	93.118**	157.021**	19.593**
Interaction (A×B×C)	6	0.001**	0.092**	247.009**	90.500**	158.043**	423.152**	0.023**	0.056**	63.390	559.624	277.420**	454.686**
Error	36	0.220	8.005	43.110	553.636	1640.870	2359.695	0.103	6.304	45.772	526.894	2192.502	2707.590

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix VII. Summary of analysis of variance for Leaf Area Index at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value											
		1st year LAI						2nd year LAI					
		CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage
Replication	2	0.008	0.479	1.041	1.432	2.312	1.602	0.008	0.384	0.926	1.299	3.003	2.078
Factor (A)	2	0.005**	0.085**	0.303**	0.304**	0.784**	0.321**	0.005**	0.097**	0.413**	0.359**	0.854**	0.333**
Error	4	0.000	0.000	0.000	0.003	0.001	0.001	0.000	0.001	0.003	0.009	0.005	0.001
Factor (B)	1	0.001**	0.008**	0.031**	0.027**	0.086**	0.033**	0.001**	0.025**	0.063**	0.065**	0.134**	0.030**
Interaction (A×B)	2	0.000	0.000	0.000*	0.002	0.000**	0.001**	0.000	0.000**	0.002	0.001**	0.002	0.001
Error	6	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.002	0.001	0.000
Factor (C)	3	0.064**	1.026**	5.357**	5.870**	11.993**	4.432**	0.062**	1.034**	5.689**	6.123**	12.397**	4.214**
Interaction (A×C)	6	0.000	0.001**	0.003**	0.002**	0.009**	0.010**	0.000	0.003	0.011**	0.010**	0.002**	0.009**
Interaction (B×C)	3	0.000**	0.000**	0.001**	0.001**	0.004**	0.004**	0.000**	0.001**	0.007**	0.005**	0.001**	0.002**
Interaction (A×B×C)	6	0.000**	0.000**	0.002**	0.001**	0.001**	0.001**	0.000**	0.001**	0.001**	0.001**	0.001**	0.001**
Error	36	0.000	0.003	0.023	0.025	0.046	0.025	0.000	0.002	0.020	0.021	0.041	0.016

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix VIII. Summary of analysis of variance for Crop Growth Rate (g m^{-2} day^{-1}) at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value									
		1st year CGR (g m^{-2} day^{-1})					2nd year CGR (g m^{-2} day^{-1})				
		CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
Replication	2	1.504	16.205	499.746	736.744	1.343	1.554	13.879	518.184	721.615	9.750
Factor (A)	2	10.349**	515.134**	1446.886**	932.883**	20.982**	9.610**	508.558**	867.623**	1295.852**	30.977**
Error	4	0.039	0.305	8.229	19.091	0.873	0.034	0.801	15.582	7.107	2.330
Factor (B)	1	0.038**	17.658**	46.911**	0.000**	0.086**	0.052**	17.693**	70.107**	72.318**	3.876
Interaction (A×B)	2	0.000**	0.256**	13.861**	10.758**	0.066**	0.002	0.322**	29.984**	21.692*	0.319**
Error	6	0.000	0.009	0.565	0.575	2.352	0.001	0.039	0.601	2.844	1.436
Factor (C)	3	5.038**	1201.599**	1806.843**	2208.127**	48.831**	5.490**	1215.818**	1812.87**	2562.218**	13.936**
Interaction (A×C)	6	0.063	7.240**	21.727**	32.656**	1.169	0.068	13.641**	30.218**	24.126*	1.274
Interaction (B×C)	3	0.005**	0.323**	0.932**	1.105**	0.495**	0.001**	0.460**	1.621**	0.211**	0.125**
Interaction (A×B×C)	6	0.001**	0.709**	2.525**	2.159**	0.200**	0.000**	0.158**	3.015	1.262	0.188**
Error	36	0.035	0.115	2.937	4.143	0.771	0.032	0.110	2.703	8.993	0.662

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix IX. Summary of analysis of variance for Relative Growth Rate (g g^{-1} day^{-1}) at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value									
		1st year RGR (g g^{-1} day^{-1})					2nd year RGR (g g^{-1} day^{-1})				
		CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
Replication	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Factor (A)	2	0.025**	0.013**	0.012**	0.002**	0.000**	0.026**	0.013**	0.009**	0.003**	0.000**
Error	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Factor (B)	1	0.000**	0.000**	0.000**	0.000**	0.000**	0.000	0.000**	0.000**	0.000	0.000**
Interaction (A×B)	2	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Error	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Factor (C)	3	0.000**	0.007**	0.006**	0.000**	0.000**	0.000**	0.008**	0.004**	0.000**	0.000**
Interaction (A×C)	6	0.000**	0.000**	0.000**	0.000**	0.000	0.000**	0.000**	0.000**	0.000**	0.000**
Interaction (B×C)	3	0.000**	0.000**	0.000**	0.000	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Interaction (A×B×C)	6	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
Error	36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

** = Significant at 1% level of probability

Appendix X. Summary of analysis of variance for Net Assimilation Rate (mg cm^{-2} day^{-1}) at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value									
		1st year NAR ($mgcm^{-2}day^{-1}$)					2nd year NAR ($mgcm^{-2}day^{-1}$)				
		CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
Replication	2	0.002	0.024	0.024	0.143	0.012	0.001	0.021	0.103	0.097	0.009
Factor (A)	2	0.434**	1.135**	2.800**	1.087**	0.035**	0.440**	1.115**	1.828**	1.709**	0.053**
Error	4	0.000	0.001	0.001	0.008	0.000	0.000	0.001	0.022	0.002	0.003
Factor (B)	1	0.000*	0.036**	0.026**	0.006*	0.000**	0.001**	0.030**	0.029*	0.018*	0.001**
Interaction (A×B)	2	0.000	0.000	0.023**	0.010**	0.000**	0.000	0.000	0.034**	0.025**	0.000**
Error	6	0.000	0.000	0.001	0.001	0.002	0.000	0.000	0.003	0.003	0.002
Factor (C)	3	0.017**	1.478**	0.077**	0.209**	0.002**	0.012**	1.671**	0.138**	0.160**	0.036**
Interaction (A×C)	6	0.004**	0.003*	0.005**	0.014*	0.001	0.006**	0.011**	0.002**	0.001**	0.000**
Interaction (B×C)	3	0.001**	0.002	0.002**	0.001**	0.000**	0.001*	0.002*	0.006**	0.000**	0.000**
Interaction (A×B×C)	6	0.000**	0.002	0.005**	0.002**	0.000**	0.000**	0.001	0.005**	0.001**	0.000**
Error	36	0.000	0.001	0.011	0.005	0.001	0.000	0.001	0.007	0.006	0.001

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix XI. Summary of analysis of variance for Leaf Area Ratio ($cm^2\ g^{-1}$) at different growth stages of wheat in both the experimental years

Sources of variation	Degrees of freedom (df)	Mean square value									
		1st year LAR ($cm^2\ g^{-1}$)					2nd year LAR ($cm^2\ g^{-1}$)				
		CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
Replication	2	428.598	501.849	48.147	6.707	2.720	194.522	328.993	62.043	23.385	1.959
Factor (A)	2	618.690**	1486.557**	344.598**	54.086**	18.325**	520.575**	1054.041**	417.249**	81.451**	16.885**
Error	4	10.317	6.185	0.375	0.100	0.267	12.077	2.694	6.547	4.758	0.999
Factor (B)	1	34.910*	387.022**	101.857**	13.200**	2.140*	103.963*	244.581**	111.664**	31.532**	15.590**
Interaction (A×B)	2	8.097	8.142**	5.390**	0.866	0.171**	0.969**	2.683**	5.573	0.748**	0.177**
Error	6	5.461	0.322	0.260	0.244	0.303	13.402	4.757	2.896	1.222	0.275
Factor (C)	3	3385.04**	11266.38**	2085.007**	317.228**	149.835**	2064.998**	13309.19**	3203.51**	544.393**	165.716**
Interaction (A×C)	6	191.641**	318.779**	71.285**	5.506	1.344	242.308**	68.533**	28.339	5.288	0.886
Interaction (B×C)	3	77.561**	62.346	16.930	1.695**	0.465**	51.560**	26.591	8.772**	1.312**	0.656
Interaction (A×B×C)	6	4.403**	28.556**	5.019**	0.391**	0.138**	17.328	6.458**	5.678**	0.922**	0.206**
Error	36	16.603	29.264	12.971	2.917	1.169	9.488	20.095	13.966	2.803	0.597

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix XIIA. Summary of analysis of variance for the yield and yield contributing characters of wheat in 1st year

Sources of variation	Degrees of freedom (df)	Mean square value								
		Plant height (cm)	Total tillers plant^{-1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
Replication	2	1438.036	4.933	4.201	88.894	21.440	569.977	379.655	21.256	3.116
Factor (A)	2	59.518**	0.930**	0.726**	4.246**	1.009**	37.598**	37.975**	6.929**	0.929**
Error	4	0.027	0.001	0.001	0.033	0.001	0.201	0.017	0.037	0.001
Factor (B)	1	0.152	0.166**	0.139**	1.073**	0.000**	8.981**	10.786**	0.017	0.169**
Interaction (A×B)	2	3.752**	0.001**	0.000**	0.007	0.086**	0.155	0.007**	0.506**	0.000**
Error	6	0.032	0.001	0.001	0.007	0.001	0.121	0.052	0.005	0.001
Factor (C)	3	1298.767**	15.560**	11.601**	84.643**	20.753**	676.091**	538.480**	123.045**	14.559**
Interaction (A×C)	6	2.223**	0.001**	0.008**	0.022**	0.001**	0.345**	1.399**	0.058**	0.001**
Interaction (B×C)	3	1.112**	0.001**	0.001**	0.014**	0.006**	0.019**	0.126**	0.045**	0.000**
Interaction (A×B×C)	6	0.662**	0.001**	0.001**	0.010**	0.006**	0.116**	0.081**	0.055**	0.000**
Error	36	21.123	0.088	0.049	0.930	0.256	4.864	4.474	0.205	0.054

** = Significant at 1% level of probability

Appendix XIIB. Summary of analysis of variance for the yield and yield contributing characters of wheat in 2nd year

Sources of variation	Degrees of freedom (df)	Mean square value								
		Plant height (cm)	Total tillers plant^{-1}	Effective tillers plant^{-1}	Spikelets Spike^{-1}	Spike length (cm)	Grains Spike^{-1}	1000 grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
Replication	2	1427.754	6.530	3.445	77.221	33.601	435.201	372.869	18.754	3.074
Factor (A)	2	63.103**	1.286**	0.833**	6.851**	2.079**	46.225**	40.868**	6.371**	1.356**
Error	4	0.065	0.000	0.001	0.047	0.006	0.026	0.047	0.014	0.002
Factor (B)	1	0.614	0.180**	0.154**	0.974**	0.014	5.373**	9.167**	0.010	0.330**
Interaction (A×B)	2	3.492**	0.001**	0.000**	0.006**	0.111**	0.099	0.022**	0.260**	0.006*
Error	6	0.192	0.002	0.000	0.011	0.003	0.034	0.113	0.005	0.001
Factor (C)	3	1232.358**	18.932**	13.921**	117.985**	32.334**	810.222**	691.166**	89.856**	16.366**
Interaction (A×C)	6	1.353**	0.014**	0.008**	0.042**	0.085**	1.634**	1.005**	0.017**	0.051
Interaction (B×C)	3	0.432**	0.000**	0.003**	0.011**	0.023**	0.196**	0.224**	0.057**	0.011**
Interaction (A×B×C)	6	0.624**	0.002**	0.001**	0.006**	0.019**	0.072**	0.136**	0.035**	0.002**
Error	36	19.607	0.078	0.058	1.061	0.260	5.410	4.080	0.290	0.037

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix XIIIA. Summary of analysis of variance for nutritional composition of wheat grain per 100g in 1st year

Sources of variation	Degrees of freedom (df)	Mean square value									
		Protein (g)	Carbohydrate (g)	Starch (g)	p^H	TSS (m mol g^{-1})	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
Replication	2	20.850	730.629	556.255	4.825	1.999	0.561	82.215	81.54.772	0.987	0.651
Factor (A)	2	0.922**	10.539**	11.676**	0.043**	0.829**	0.250**	24.879**	7760.291**	0.925**	0.261**
Error	4	0.000	0.048	0.011	0.000	0.002	0.000	0.014	10.991	0.000	0.000
Factor (B)	1	0.159**	2.167**	2.072**	0.007**	0.154**	0.022**	8.273**	1412.683**	0.163**	0.092**
Interaction (A×B)	2	0.000	0.168**	0.039*	0.000	0.000**	0.000	0.001**	6.433	0.000**	0.000**
Error	6	0.000	0.015	0.004	0.000	0.001	0.000	0.003	3.592	0.000	0.000
Factor (C)	3	18.358**	300.211**	276.898**	1.567**	12.299**	3.280**	360.268**	117759.717**	12.608**	3.403**
Interaction (A×C)	6	0.000**	0.043**	0.018**	0.000**	0.005**	0.001**	0.025**	87.820**	0.001**	0.000**
Interaction (B×C)	3	0.000**	0.009**	0.004**	0.000**	0.001**	0.000**	0.015**	11.489**	0.001**	0.001**
Interaction (A×B×C)	6	0.002**	0.044**	0.016**	0.000**	0.001**	0.000**	0.017**	9.357**	0.000**	0.000**
Error	36	0.195	7.425	5.945	0.065	0.015	0.005	1.271	119.271	0.013	0.009

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix XIIIB. Summary of analysis of variance for nutritional composition of wheat grain per 100g in 2nd year

Sources of variation	Degrees of freedom (df)	Mean square value									
		Protein (g)	Carbohydrate (g)	Starch (g)	pH	TSS (m mol g^{-1})	Ash (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)
Replication	2	21.470	700.877	544.530	4.745	2.202	0.629	77.764	12853.336	0.775	1.111
Factor (A)	2	0.908**	9.525**	10.768**	0.040**	0.857**	0.277**	25.312**	8806.921**	0.845**	0.252**
Error	4	0.000	0.107	0.057	0.000	0.002	0.001	0.111	7.371	0.000	0.000
Factor (B)	1	0.165**	1.593**	1.587**	0.006**	0.123**	0.025**	1.626**	1277.331**	0.179**	0.038**
Interaction (A×B)	2	0.000*	0.219**	0.168**	0.000**	0.002**	0.000**	0.012**	13.065**	0.000**	0.000*
Error	6	0.000	0.020	0.008	0.000	0.002	0.000	0.012	1.080	0.000	0.000
Factor (C)	3	18.826**	289.952**	271.333**	1.512**	12.164**	3.311**	353.590**	124584.654**	11.822**	3.466**
Interaction (A×C)	6	0.001**	0.044**	0.027**	0.000**	0.006**	0.000**	0.160**	42.120**	0.004**	0.001**
Interaction (B×C)	3	0.000**	0.010**	0.009**	0.000**	0.000**	0.000**	0.009**	6.116**	0.000**	0.000**
Interaction (A×B×C)	6	0.002**	0.045**	0.023**	0.000**	0.000**	0.000**	0.014**	6.723**	0.001**	0.000**
Error	36	0.214	6.789	5.573	0.063	0.017	0.005	1.043	143.151	0.010	0.008

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Appendix XIV. Interaction effect of late seeding and variety on total dry matter (g m^{-2}) at different growth stages of wheat

Parameter / Interaction	1st year TDM (gm^{-2})						2nd year TDM (gm^{-2})					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**	**CRI Stage**	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
D_1V_1	9.442	49.886b	359.779b	878.332b	1341.368b	1610.641a	9.254	48.685b	344.054	784.374b	1276.405b	1557.212b
D_1V_2	**9.582**	**50.787a**	**378.535a**	**908.148a**	**1376.482a**	**1648.004a**	**9.423**	**49.509a**	**362.971**	**809.465a**	**1335.655a**	**1624.104a**
D_2V_1	9.096	48.226d	329.195d	807.959d	1247.467d	1511.595b	8.789	46.883d	306.826	694.979d	1174.454d	1455.345c
D_1V_2	9.273	49.048c	345.566c	858.025c	1282.732c	1545.884b	9.034	47.816c	328.209	761.704c	1240.992c	1532.54b
D_3V_1	8.809	46.692f	284.891f	748.986f	1138.337f	1403.892c	8.446	45.082f	267.886	646.033f	1075.422f	1353.076d
D_1V_2	8.922	47.248e	305.510e	776.969e	1177.592e	1447.427c	8.66	46.023e	283.743	671.638e	1138.573e	1434.006c
LS	NS	0.050	0.010	0.010	0.010	0.010	NS	0.010	NS	0.010	0.010	0.010
CV	5.10	5.82	1.97	2.84	3.21	3.18	3.60	5.30	2.14	3.15	3.88	3.49

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XV. Interaction effect of late seeding and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat

Parameter / Interaction	1st year TDM (gm^{-2})						2nd year TDM (gm^{-2})					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**	**CRI Stage**	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
D_1M_0	7.784g	40.128gh	198.388j	586.617j	894.501j	1117.639j	7.578	38.154g	164.826j	479.499j	829.302j	1097.317j
D_1M_1	9.307def	47.270def	305.565g	782.842g	1205.59g	1473.861g	9.081	46.478de	299.513g	695.351g	1145.355g	1429.409g
D_1M_2	9.972bcd	53.556bc	428.438d	995.622d	1510.569d	1788.776d	9.877	52.342bc	419.918d	909.77d	1453.03d	1743.809d
D_1M_3	**10.984a**	**60.392a**	**544.238a**	**1207.879a**	**1825.041a**	**2137.015a**	**10.818**	**59.414a**	**529.794a**	**1103.057a**	**1796.432a**	**2092.096a**
D_2M_0	7.372gh	39.397gh	149.752k	517.447k	820.206k	1020.2k	6.982	37.102g	135.033k	415.327k	744.82k	1002.91k
D_2M_1	8.976ef	45.256ef	275.819h	724.014h	1097.647h	1356.686h	8.586	44.374ef	247.343h	618.258h	1047.417h	1326.658h
D_2M_2	9.772cd	51.434cd	399.001e	938.196e	1401.74e	1691.667e	9.642	50.524cd	379.133e	833.191e	1359.702e	1649.417e
D_2M_3	10.617ab	58.459a	524.950b	1152.311b	1740.806b	2046.405b	10.436	57.399a	508.56b	1046.59b	1678.954b	1996.786b
D_3M_0	6.906h	37.960h	111.784l	448.076l	719.362l	927.104l	6.373	35.958g	106.211l	351.901l	648.125l	894.183l
D_3M_1	8.659f	43.953fg	237.987i	667.259i	990.093i	1245.4i	8.203	42.266f	209.954i	549.126i	949.413i	1232.459i
D_3M_2	9.548de	49.598cde	352.442f	868.006f	1309.797f	1601.312f	9.395	48.62cd	330.774f	765.89f	1258.596f	1553.379f
D_3M_3	10.348abc	56.369ab	478.588c	1068.57c	1612.605c	1928.823c	10.24	55.365ab	456.318c	968.424c	1571.857c	1894.143c
LS	0.010	0.010	0.010	0.010	0.010	0.010	NS	0.010	0.010	0.010	0.010	0.010
CV	5.10	5.82	1.97	2.84	3.21	3.18	3.60	5.30	2.14	3.15	3.88	3.49

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XVI. Interaction effect of variety and micronutrient on total dry matter (g m^{-2}) at different growth stages of wheat

Parameter / Interaction	1st year TDM (gm^{-2})						2nd year TDM (gm^{-2})					
	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage
V_1M_0	7.254d	39.039d	142.611	497.123h	793.861d	1000.337d	6.808d	36.656d	124.754h	398.703h	712.782g	961.917h
V_1M_1	8.916c	45.126c	262.730	706.814f	1076.417c	1332.186c	8.505c	43.897c	244.086f	599.539f	1015.278f	1292.203f
V_1M_2	9.721b	51.064b	387.534	917.111d	1390.12b	1680.085b	9.588b	50.078b	363.774d	814.751d	1322.029d	1610.134d
V_1M_3	10.571a	57.842a	505.611	1125.987b	1709.166a	2022.23a	10.418a	56.903a	492.408b	1020.856b	1651.62b	1956.591b
V_2M_0	7.454d	39.285d	164.005	537.637g	828.852d	1042.957d	7.148d	37.488d	145.959g	432.449g	768.717g	1034.356g
V_2M_1	9.046c	45.860c	283.517	742.595e	1119.137c	1385.113c	8.741c	44.848c	260.454e	642.284e	1079.511e	1366.814e
V_2M_2	9.808b	51.995b	399.053	950.772c	1424.617b	1707.752b	9.689b	50.913b	389.443c	857.817c	1392.189c	1687.604c
V_2M_3	**10.727a**	**58.971a**	**526.240**	**1159.852a**	**1743.136a**	**2052.599a**	**10.579a**	**57.882a**	**504.04a**	**1057.858a**	**1713.209a**	**2032.093a**
LS	0.010	0.010	NS	0.010	0.010	0.010	0.010	0.010	0.050	0.010	0.010	0.010
CV	5.10	5.82	1.97	2.84	3.21	3.18	3.60	5.30	2.14	3.15	3.88	3.49

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XVII. Interaction effect of late seeding and variety on leaf area index at different growth stages of wheat

Parameter / Interaction	1st year LAI						2nd year LAI					
	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage	CRI Stage	Tillering Stage	Booting Stage	Heading Stage	Anthesis Stage	Physiological maturity Stage
D_1V_1	0.272	1.287	2.64b	2.877	4.166b	2.897a	0.262	1.264ab	2.544	2.787ab	4.037	2.786
D_1V_2	**0.276**	**1.315**	**2.683a**	**2.917**	**4.238a**	**2.923a**	**0.266**	**1.297a**	**2.591**	**2.832a**	**4.112**	**2.81**
D_2V_1	0.258	1.24	2.524d	2.784	3.981d	2.791c	0.247	1.201cd	2.411	2.66c	3.831	2.662
D_1V_2	0.264	1.256	2.556c	2.804	4.052c	2.844b	0.255	1.241bc	2.463	2.729b	3.935	2.707
D_3V_1	0.242	1.174	2.412f	2.645	3.808f	2.656e	0.232	1.135e	2.266	2.532d	3.658	2.535
D_1V_2	0.249	1.191	2.462e	2.7	3.873e	2.705d	0.238	1.172de	2.344	2.598cd	3.737	2.59
LS	NS	NS	0.050	NS	0.010	0.010	NS	0.010	NS	0.010	NS	NS
CV	4.08	4.33	5.94	5.68	5.31	5.65	4.28	3.81	5.74	5.34	5.24	4.78

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XVIII. Interaction effect of late seeding and micronutrient on leaf area index at different growth stages of wheat

Parameter / Interaction	1st year LAI						2nd year LAI					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**	**CRI Stage**	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
D_1M_0	0.203	1.012i	1.979h	2.174g	3.188h	2.331g	0.195	1.007	1.891h	2.101f	3.054i	2.237g
D_1M_1	0.266	1.232fg	2.572efg	2.804def	3.915fg	2.792def	0.255	1.207	2.48ef	2.711d	3.813fg	2.674de
D_1M_2	0.297	1.406cd	2.874bcd	3.12bc	4.52cd	3.084bc	0.286	1.364	2.792bcd	3.038bc	4.375cd	2.975bc
D_1M_3	**0.332**	**1.554a**	**3.221a**	**3.491a**	**5.184a**	**3.434a**	**0.321**	**1.545**	**3.108a**	**3.387a**	**5.055a**	**3.306a**
D_2M_0	0.183	0.964i	1.808hi	2.033g	3.051h	2.196gh	0.173	0.938	1.686hi	1.928fg	2.897ij	2.09g
D_2M_1	0.252	1.185gh	2.457fg	2.701ef	3.755fg	2.704ef	0.239	1.149	2.362fg	2.614de	3.627gh	2.566ef
D_2M_2	0.288	1.328de	2.778cde	3.041bcd	4.306de	3.018bcd	0.278	1.322	2.688cde	2.95c	4.165de	2.876cd
D_2M_3	0.322	1.515ab	3.117ab	3.403a	4.954ab	3.351a	0.313	1.476	3.012ab	3.287a	4.843ab	3.207a
D_3M_0	0.162	0.868j	1.728i	1.938g	2.916h	1.982h	0.154	0.822	1.517i	1.752g	2.718j	1.888h
D_3M_1	0.232	1.118h	2.324g	2.553f	3.582g	2.605f	0.22	1.099	2.203g	2.454e	3.44h	2.464f
D_3M_2	0.276	1.287ef	2.672def	2.918cde	4.081ef	2.9cde	0.267	1.262	2.582def	2.848cd	3.99ef	2.78cd
D_3M_3	0.312	1.456bc	3.025abc	3.28ab	4.782bc	3.235ab	0.3	1.432	2.919abc	3.206ab	4.641bc	3.118ab
LS	NS	0.010	0.010	0.010	0.010	0.010	NS	NS	0.010	0.010	0.010	0.010
CV	4.08	4.33	5.94	5.68	5.31	5.65	4.28	3.81	5.74	5.34	5.24	4.78

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.

NS = Not significant

Appendix XIX. Interaction effect of variety and micronutrient on leaf area index at different growth stages of wheat

Parameter / Interaction	1st year LAI						2nd year LAI					
	CRI Stage	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**	**CRI Stage**	**Tillering Stage**	**Booting Stage**	**Heading Stage**	**Anthesis Stage**	**Physiological maturity Stage**
V_1M_0	0.177c	0.934d	1.813d	2.022d	3.033d	2.126d	0.169d	0.892d	1.641d	1.874d	2.85d	2.036d
V_1M_1	0.247b	1.169c	2.424c	2.661c	3.724c	2.687c	0.234c	1.137c	2.319c	2.562c	3.588c	2.553c
V_1M_2	0.286ab	1.331b	2.761b	3.015b	4.258b	2.985b	0.276abc	1.298b	2.669b	2.924b	4.136b	2.862b
V_1M_3	0.321a	1.5a	3.104a	3.377a	4.924a	3.326a	0.309a	1.472a	2.999a	3.279a	4.793a	3.194a
V_2M_0	0.188c	0.962d	1.864d	2.075d	3.07d	2.213d	0.179d	0.952d	1.755d	1.98d	2.93d	2.108d
V_2M_1	0.252b	1.188c	2.479c	2.711c	3.777c	2.713c	0.242bc	1.166c	2.378c	2.624c	3.665c	2.583c
V_2M_2	0.289ab	1.35b	2.788b	3.037b	4.347b	3.016b	0.278ab	1.334b	2.705b	2.966b	4.218b	2.891b
V_2M_3	**0.323a**	**1.517a**	**3.138a**	**3.405a**	**5.022a**	**3.354a**	**0.313a**	**1.496a**	**3.027a**	**3.307a**	**4.899a**	**3.227a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	4.08	4.33	5.94	5.68	5.31	5.65	4.28	3.81	5.74	5.34	5.24	4.78

Appendix XX. Interaction effect of late seeding and variety on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year CGR (g m^{-2} day^{-1})					2nd year CGR (g m^{-2} day^{-1})				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
D_1V_1	2.696c	20.659a	34.57d	30.869d	8.976a	2.629	19.691b	29.355c	32.802d	9.36b
D_1V_2	2.747b	**21.85a**	35.307d	31.222d	9.051a	2.672	**20.897a**	29.766c	35.079c	9.615b
D_2V_1	2.609d	14.048bc	47.876b	**43.951a**	10.565a	2.54	12.997d	38.815b	**47.948a**	11.235ab
D_1V_2	2.652cd	14.826b	**51.246a**	42.471b	10.526a	2.585	14.019c	**43.35a**	47.929a	11.662a
D_3V_1	3.788a	11.91d	46.41c	38.935c	10.622a	3.664	11.14f	37.815b	42.939b	11.106ab
D_1V_2	**3.833a**	12.913cd	47.146bc	40.062c	**10.793a**	**3.736**	11.886e	38.789b	46.694a	**11.817a**
LS	0.010	0.010	0.010	0.010	0.010	NS	0.010	0.010	0.050	0.010
CV	6.13	2.11	3.92	5.37	8.70	6.00	2.19	4.53	7.10	7.53

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXI. Interaction effect of late seeding and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year CGR (g m^{-2} day^{-1})					2nd year CGR (g m^{-2} day^{-1})				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
D_1M_0	2.156	10.551h	25.882g	20.526i	7.438	2.039	8.445h	20.978h	23.32h	8.934
D_1M_1	2.531	17.22e	31.818f	28.183h	8.942	2.493	16.869e	26.389fg	30g	9.468
D_1M_2	2.905	24.992b	37.812e	34.33ef	9.274	2.831	24.505b	32.657e	36.217f	9.693
D_1M_3	3.294	**32.256a**	44.243d	41.144d	10.399	3.24	**31.358a**	38.217d	46.225cd	9.856
D_2M_0	2.135	5.518j	36.77e	30.276gh	8	2.008	4.896i	28.029f	32.949fg	10.323
D_2M_1	2.419	11.528g	44.82d	37.363e	10.362	2.386	10.148g	37.091d	42.916de	11.169
D_2M_2	2.777	17.378e	53.919c	46.354c	11.597	2.725	16.43e	45.406c	52.651b	11.589
D_2M_3	3.189	23.325c	**62.736a**	**58.85a**	12.224	3.131	22.558c	**53.803a**	**63.236a**	12.713
D_3M_0	3.106	3.691k	33.629f	27.129h	8.31	2.959	3.513j	24.569g	29.622g	9.843
D_3M_1	3.53	9.702i	42.927d	32.284fg	10.212	3.406	8.384h	33.917e	40.029e	11.322
D_3M_2	4.005	15.142f	51.557c	44.179cd	11.661	3.922	14.108f	43.512c	49.27bc	11.791
D_3M_3	**4.602**	21.111d	58.998b	54.404b	**12.649**	**4.512**	20.048d	51.211b	60.343a	**12.891**
LS	NS	0.010	0.010	0.010	NS	NS	0.010	0.010	0.050	NS
CV	6.13	2.11	3.92	5.37	8.70	6.00	2.19	4.53	7.10	7.53

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXII. Interaction effect of variety and micronutrient on crop growth rate (g m^{-2} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year CGR (g m^{-2} day^{-1})					2nd year CGR (g m^{-2} day^{-1})				
	CRI-Tillering Stage	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**	**CRI-Tillering Stage**	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**
V_1M_0	2.464d	5.999h	31.2d	26.201d	7.763d	2.316d	5.054h	23.938f	27.713d	9.369d
V_1M_1	2.806c	12.234f	39.143c	32.257c	9.641c	2.734c	11.359f	31.248e	36.748c	10.459bc
V_1M_2	3.197b	18.869d	46.687b	41.66b	10.985ab	3.131b	17.674d	39.601c	44.96b	10.885bc
V_1M_3	3.657a	25.055b	54.777a	**51.555a**	**11.829a**	3.596a	24.352b	46.526b	55.496a	11.555ab
V_2M_0	2.467d	7.174g	32.987d	25.753d	8.068d	2.354d	6.182g	25.113f	29.548d	10.03cd
V_2M_1	2.847c	13.399e	40.567c	32.963c	10.036bc	2.79c	12.242e	33.684d	38.549c	10.847bc
V_2M_2	3.261b	19.473c	48.838b	41.582b	10.703abc	3.188b	19.022c	41.449c	47.132b	11.163abc
V_2M_3	**3.733a**	**26.073a**	**55.874a**	51.377a	11.686a	**3.659a**	**24.957a**	**48.962a**	**57.707a**	**12.085a**
LS	0.010	0.050	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	6.13	2.11	3.92	5.37	8.70	6.00	2.19	4.53	7.10	7.53

Appendix XXIII. Interaction effect of late seeding and variety on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year RGR (g g^{-1} day^{-1})					2nd year RGR (g g^{-1} day^{-1})				
	CRI-Tillering Stage	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**	**CRI- Tillering Stage**	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**
D_1V_1	0.111b	0.128a	0.062a	0.028a	0.006a	0.11b	0.125a	0.058a	0.033a	0.007a
D_1V_2	0.111b	**0.131a**	0.06a	0.028a	0.006a	0.11b	**0.128a**	0.056a	0.034a	0.007a
D_2V_1	0.111b	0.091a	0.096a	**0.044a**	0.008a	0.111b	0.088a	0.088a	**0.054a**	0.009a
D_1V_2	0.111b	0.094a	0.096a	0.04a	0.008a	0.111b	0.092a	0.089a	0.05a	0.009a
D_3V_1	**0.167a**	0.084a	**0.105a**	0.042a	**0.009a**	0.168a	0.082a	**0.095a**	0.053a	0.01a
D_1V_2	0.167a	0.088a	0.101a	0.042a	0.008a	**0.167a**	0.086a	0.092a	0.054a	**0.01a**
LS	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
CV	0.86	2.72	2.10	5.32	9.45	2.43	2.25	2.94	6.32	10.5

Appendix XXIV. Interaction effect of late seeding and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year RGR (g g^{-1} day^{-1})					2nd year RGR (g g^{-1} day^{-1})				
	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
D_1M_0	0.109b	0.107abc	0.072bc	0.028a	0.008	0.107c	0.098a-d	0.072abc	0.036a	0.01a
D_1M_1	0.108b	0.125ab	0.062c	0.029a	0.007	0.109bc	0.124abc	0.056bc	0.033a	0.008a
D_1M_2	0.112b	0.139ab	0.056c	0.028a	0.006	0.111bc	0.139ab	0.052c	0.031a	0.006a
D_1M_3	0.114b	**0.146a**	0.053c	0.028a	0.005	0.114bc	**0.146a**	0.049c	0.033a	0.005a
D_2M_0	0.112b	0.067c	0.124ab	0.046a	0.008	0.111bc	0.065d	0.112ab	0.058a	0.012a
D_2M_1	0.108b	0.09abc	0.096abc	0.041a	0.009	0.109bc	0.086bcd	0.091abc	0.053a	0.01a
D_2M_2	0.111b	0.102abc	0.085abc	0.04a	0.008	0.11bc	0.101a-d	0.078abc	0.049a	0.008a
D_2M_3	0.114b	0.109abc	0.079bc	0.042a	0.007	0.113bc	0.109a-d	0.072abc	0.047a	0.007a
D_3M_0	**0.17a**	0.054c	**0.139a**	**0.048a**	**0.01**	**0.173a**	0.054d	**0.119a**	**0.061a**	**0.013a**
D_3M_1	0.163ab	0.084bc	0.103abc	0.039a	0.009	0.164ab	0.08cd	0.096abc	0.055a	0.011a
D_3M_2	0.165ab	0.098abc	0.09abc	0.041a	0.008	0.165ab	0.096a-d	0.084abc	0.049a	0.008a
D_3M_3	0.17a	0.107abc	0.08bc	0.041a	0.007	0.169a	0.105a-d	0.075abc	0.048a	0.008a
LS	0.010	0.010	0.010	0.010	NS	0.010	0.010	0.010	0.010	0.010
CV	0.86	2.72	2.10	5.32	9.45	2.43	2.25	2.94	6.32	10.5

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXV. Interaction effect of variety and micronutrient on relative growth rate (g g^{-1} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year RGR (g g^{-1} day^{-1})					2nd year RGR (g g^{-1} day^{-1})				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
V_1M_0	0.131a	0.073b	**0.115a**	**0.042**	**0.009a**	0.131a	0.068b	**0.104a**	**0.052a**	0.011a
V_1M_1	0.126a	0.098ab	0.088a	0.037	0.008a	0.128a	0.096ab	0.081a	0.047a	0.01a
V_1M_2	0.129a	0.113ab	0.077a	0.037	0.007a	0.128a	0.11ab	0.072a	0.043a	0.007a
V_1M_3	0.132a	0.12a	0.071a	0.037	0.006a	0.132a	0.12a	0.065a	0.042a	0.007a
V_2M_0	0.13a	0.08ab	0.109a	0.039	0.009a	0.129a	0.076ab	0.098a	0.051a	**0.012a**
V_2M_1	0.126a	0.101ab	0.086a	0.036	0.008a	0.127a	0.098ab	0.081a	0.047a	0.009a
V_2M_2	0.13a	0.113ab	0.077a	0.035	0.007a	0.129a	0.113ab	0.071a	0.043a	0.007a
V_2M_3	**0.133a**	**0.122a**	0.07a	0.036	0.006a	**0.132a**	**0.12a**	0.066a	0.043a	0.007a
LS	0.010	0.010	0.010	NS	0.010	0.010	0.010	0.010	0.010	0.010
CV	0.86	2.72	2.10	5.32	9.45	2.43	2.25	2.94	6.32	10.5

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. NS = Not significant

Appendix XXVI. Interaction effect of late seeding and variety on net assimilation rate (mg $cm^{-2}day^{-1}$) at different growth stages of wheat

Parameter / Interaction	1st year NAR ($mgcm^{-2}day^{-1}$)					2nd year NAR ($mgcm^{-2}day^{-1}$)				
	CRI-Tillering Stage	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**	**CRI-Tillering Stage**	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**
D_1V_1	0.415	1.056	1.253c	0.874c	0.261b	0.413	1.026	1.098c	0.954c	0.288b
D_1V_2	0.413	**1.105**	1.258c	0.866c	0.259b	0.41	**1.073**	1.092c	1.007c	0.29b
D_2V_1	0.421	0.734	1.807b	**1.295a**	0.317ab	0.424	0.702	1.526b	**1.477a**	0.357ab
D_1V_2	0.419	0.774	**1.917a**	1.231b	0.31ab	0.416	0.746	**1.653a**	1.437ab	0.364a
D_3V_1	**0.655**	0.646	1.831b	1.198b	**0.335a**	**0.656**	0.627	1.555b	1.385b	0.369a
D_1V_2	0.645	0.691	1.831b	1.216b	0.334a	0.645	0.658	1.553b	1.469ab	**0.386a**
LS	NS	NS	0.010	0.010	0.010	NS	NS	0.010	0.010	0.010
CV	1.96	4.28	6.25	6.50	7.71	3.16	3.19	5.93	5.77	9.48

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXVII. Interaction effect of late seeding and micronutrient on net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year NAR ($mgcm^{-2}day^{-1}$)					2nd year NAR ($mgcm^{-2}day^{-1}$)				
	CRI-Tillering Stage	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**	**CRI-Tillering Stage**	**Tillering-Booting Stage**	**Booting-Heading Stage**	**Heading-Anthesis Stage**	**Anthesis-Physiological maturity Stage**
D_1M_0	0.428c	0.747h	1.263c	0.768g	0.278	0.411c	0.61g	1.071ef	0.902e	0.352bc
D_1M_1	0.402c	0.947e	1.181c	0.844fg	0.271	0.408c	0.955d	1.013f	0.926e	0.296de
D_1M_2	0.408c	1.219b	1.26c	0.907ef	0.248	0.411c	1.231b	1.118ef	0.985e	0.268ef
D_1M_3	0.417c	**1.411a**	1.319c	0.96e	0.245	0.416c	**1.403a**	1.177e	1.109d	0.24f
D_2M_0	0.455c	0.419k	**1.938a**	1.202bc	0.309	0.442c	0.389i	1.558bcd	1.379bc	0.423a
D_2M_1	0.402c	0.661i	1.733b	1.157c	0.326	0.413c	0.603g	1.485cd	1.382bc	0.366bc
D_2M_2	0.409c	0.886f	1.852ab	1.27b	0.322	0.407c	0.855e	1.607abc	1.492ab	0.333cd
D_2M_3	0.414c	1.05c	1.925a	**1.424a**	0.299	0.418c	1.048c	**1.708a**	**1.575a**	0.32cd
D_3M_0	**0.74a**	0.301l	1.853ab	1.142c	**0.346**	**0.741a**	0.313j	1.494cd	1.343c	**0.43a**
D_3M_1	0.628b	0.59j	1.758ab	1.052d	0.334	0.624b	0.529h	1.45d	1.362ab	0.389ab
D_3M_2	0.611b	0.799g	1.842ab	1.27b	0.338	0.613b	0.766f	1.6abc	1.449abc	0.353bc
D_3M_3	0.62b	0.984d	1.872ab	1.364a	0.32	0.623b	0.961d	1.672ab	1.555a	0.337bcd
LS	0.010	0.050	0.010	0.050	NS	0.010	0.010	0.010	0.010	0.010
CV	1.96	4.28	6.25	6.50	7.71	3.16	3.19	5.93	5.77	9.48

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXVIII. Interaction effect of variety and micronutrient on net assimilation rate (mg $cm^{-2}day^{-1}$) at different growth stages of wheat

Parameter / Interaction	1st year NAR ($mgcm^{-2}day^{-1}$)					2nd year NAR ($mgcm^{-2}day^{-1}$)				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
V_1M_0	0.553a	0.452	1.657ab	1.055de	0.311a	0.545a	0.407g	1.381bcd	1.197c	0.392ab
V_1M_1	0.479b	0.706	1.548b	1.014e	0.306a	0.483b	0.678e	1.285d	1.206c	0.348c
V_1M_2	0.475b	0.959	1.621ab	1.159bc	0.309a	0.478b	0.925c	1.419bc	1.291bc	0.317cd
V_1M_3	0.481b	1.132	1.697ab	1.261a	0.292a	0.485b	1.13a	1.487ab	1.396a	0.295d
V_2M_0	0.529a	0.525	1.712a	1.019e	0.31a	0.518a	0.468f	1.368cd	1.219c	0.411a
V_2M_1	0.476b	0.759	1.567ab	1.021e	0.314a	0.48b	0.714d	1.348cd	1.24bc	0.353bc
V_2M_2	0.477b	0.978	1.682ab	1.139cd	0.296a	0.476b	0.976b	1.464abc	1.327ab	0.319cd
V_2M_3	0.486b	1.165	1.714a	1.239ab	0.284a	0.487b	1.144a	1.551a	1.43a	0.303d
LS	0.010	NS	0.010	0.010	0.010	0.050	0.050	0.010	0.010	0.010
CV	1.96	4.28	6.25	6.50	7.71	3.16	3.19	5.93	5.77	9.48

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXIX. Interaction effect of late seeding and variety on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year LAR (cm^2 g^{-1})					2nd year LAR (cm^2 g^{-1})				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
D_1V_1	267.551	125.252e	49.698d	32.634	24.268cd	266.956a	128.666cd	53.353	34.629d	24.538b
D_1V_2	268.792	121.784f	48.069e	32.14	23.989d	268.904a	125.487d	51.706	33.689d	23.683c
D_2V_1	264.725	132.601c	53.513c	34.23	25.071bc	263.724ab	135.315b	58.012	36.633bc	25.255b
D_1V_2	265.039	126.803d	50.069d	32.979	24.852bcd	266.432a	130.871c	54.471	34.998cd	24.445bc
D_3V_1	256.895	141.468a	57.43a	35.785	26.144a	257.547c	142.03a	61.994	38.536a	26.348a
D_1V_2	259.518	136.823b	55.367b	34.961	25.607ab	260.102bc	138.595b	59.711	37.139ab	25.221b
LS	NS	0.010	0.010	NS	0.010	0.010	0.010	NS	0.010	0.010
CV	1.54	4.14	6.88	5.05	4.33	1.17	3.36	6.61	4.66	3.10

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXX. Interaction effect of late seeding and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year LAR (cm^2 g^{-1})					2nd year LAR (cm^2 g^{-1})				
	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
D_1M_0	255.325b	144.776c	57.609c	36.147	27.222	261.004e	161.264b	67.225	39.695	27.315
D_1M_1	269.449a	131.599d	53.056cd	34.116	24.934	267.163bcd	130.173e	55.364	35.986	25.1
D_1M_2	**274.977a**	113.804f	44.564ef	30.634	22.852	270.727abc	112.864fg	46.003	31.65	22.801
D_1M_3	272.934a	103.894g	40.307f	28.652	21.505	**272.826a**	104.004h	41.527	29.306	21.226
D_2M_0	245.807c	161.969b	64.573b	38.05	28.285	251.143f	167.632ab	72.075	42.182	28.472
D_2M_1	268.249a	136.707cd	55.628c	35.837	26.319	265.823cde	142.519d	61.66	38.186	26.028
D_2M_2	271.044a	115.664ef	46.116ef	31.558	23.534	271.175abc	118.111f	48.994	32.865	23.245
D_2M_3	274.428a	104.468g	40.847f	28.973	21.709	272.171ab	104.111h	42.239	30.028	21.654
D_3M_0	230.506d	**181.825a**	**75.234a**	**41.65**	**29.426**	233.101g	**174.614a**	**79.903**	**45.717**	**29.9**
D_3M_1	258.714b	143.288c	58.575c	37.331	27.763	263.162de	151.636c	66.124	40.237	27.125
D_3M_2	269.948a	122.677e	48.863de	32.357	23.885	268.294a-d	125.2e	52.39	34.221	23.936
D_3M_3	273.659a	108.792fg	42.922ef	30.152	22.427	270.743abc	109.799gh	44.994	31.176	22.176
LS	0.010	0.010	0.010	NS	NS	0.010	0.010	NS	NS	NS
CV	1.54	4.14	6.88	5.05	4.33	1.17	3.36	6.61	4.66	3.10

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT.
NS = Not significant

Appendix XXXI. Interaction effect of variety and micronutrient on leaf area ratio (cm^2 g^{-1}) at different growth stages of wheat

Parameter / Interaction	1st year LAR (cm^2 g^{-1})					2nd year LAR (cm^2 g^{-1})				
	CRI-Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage	CRI- Tillering Stage	Tillering-Booting Stage	Booting-Heading Stage	Heading-Anthesis Stage	Anthesis-Physiological maturity Stage
V_1M_0	240.203d	**167.802**	**68.406**	**39.453a**	**28.554a**	244.797e	**171.267**	**75.216a**	**43.441a**	**29.223**
V_1M_1	265.109b	139.488	56.805	36.241bc	26.705bc	264.678c	143.075	62.312b	38.98b	26.66
V_1M_2	272.151a	118.158	47.09	31.767d	23.474d	269.248ab	120.558	50.246c	33.484c	23.719
V_1M_3	**274.766a**	106.981	41.889	29.403e	21.91e	**272.247a**	106.448	43.372de	30.491de	21.919
V_2M_0	247.556c	157.912	63.205	37.778ab	28.068ab	252.034d	164.406	70.918a	41.621a	27.901
V_2M_1	265.833b	134.908	54.702	35.282c	25.973c	266.087bc	139.81	59.787b	37.292b	25.509
V_2M_2	271.829a	116.605	45.938	31.266de	23.373d	270.882a	116.893	48.011cd	32.34cd	22.936
V_2M_3	272.581a	104.455	40.828	29.114e	21.85e	271.579a	105.495	42.468e	29.849e	21.452
LS	0.010	NS	NS	0.010	0.010	0.010	NS	0.010	0.010	NS
CV	1.54	4.14	6.88	5.05	4.33	1.17	3.36	6.61	4.66	3.10

In a column the figures bearing same letter (s) or without letter are identical and those having dissimilar letters differed significantly as per DMRT. NS = Not significant

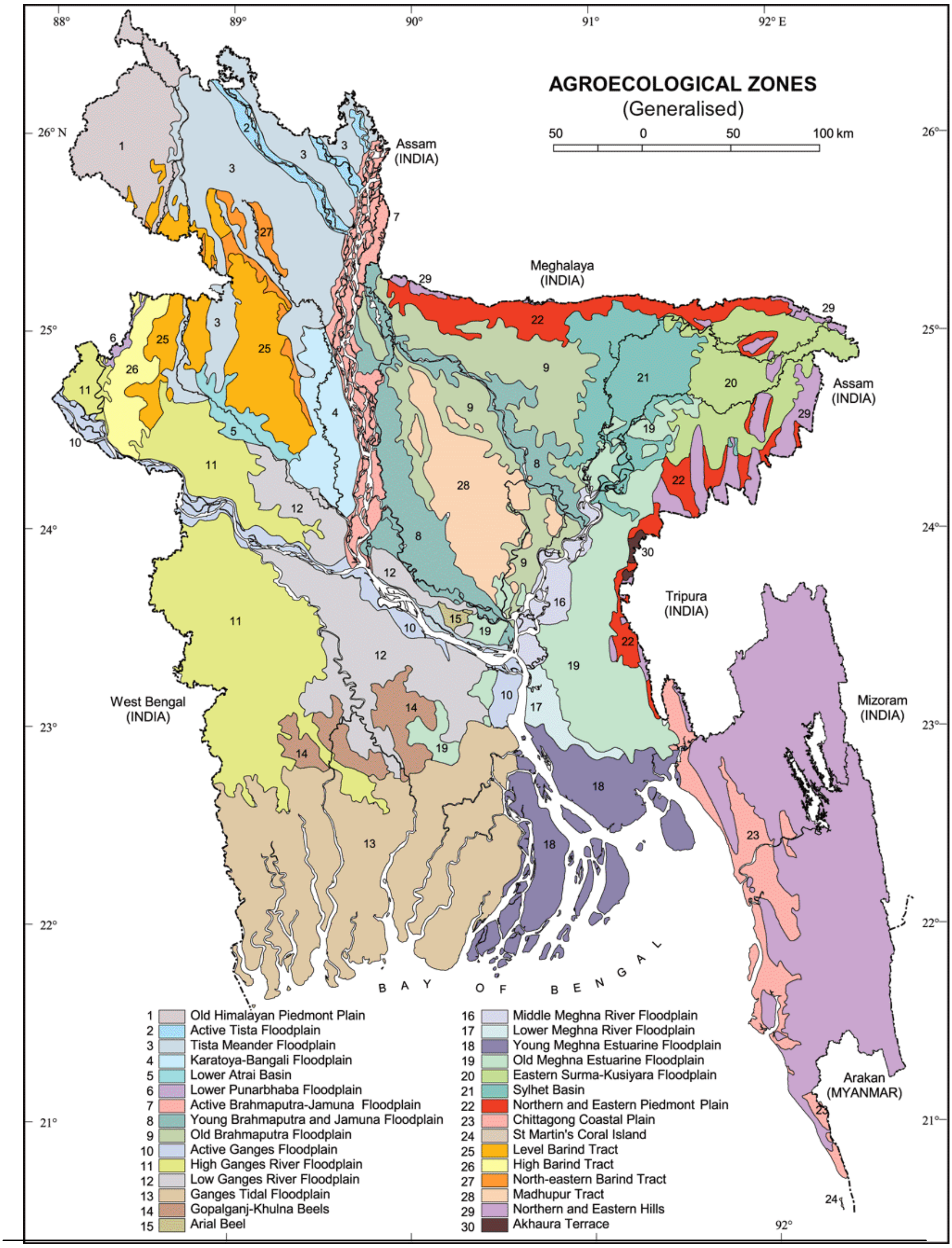


Plate 6. Agro-Ecological Zone in Bangladesh

A: Comparison among 25 November, 10 December and 25 December of wheat in BARI Gom 28

B: Comparison among 25 November and 25 December of wheat in BARI Gom 28

C: BARI Gom 26 and BARI Gom 28 at 25 November

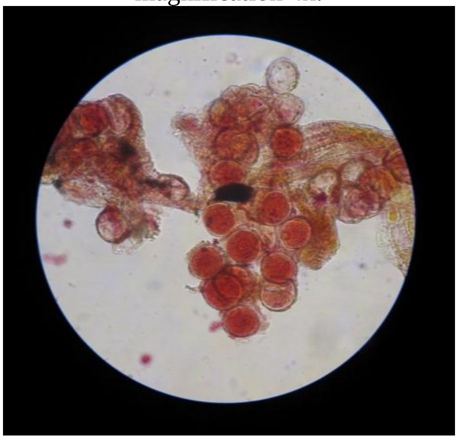
D: BARI Gom 26 and BARI Gom 28 at 10 December

E: BARI Gom 26 and BARI Gom 28 at 25 December

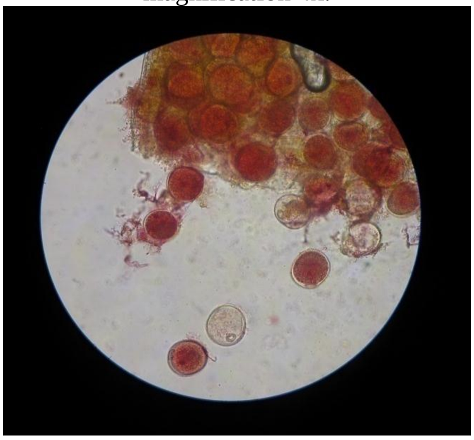
Plate 7. Comparison among sowing dates on growth stages of wheat in BARI Gom 28 (A-B) and comparison among varieties on growth stages of wheat at different sowing dates (C-E)

A: Stamens and pistils of wheat flower at Mo in late seeding heat stress condition. Photograph magnification 4x.

B: Stamens and pistils of wheat flower at M_3 in late seeding heat stress condition. Photograph magnification 4x.



C: Pollen grains of wheat flower at Mo in late seeding heat stress condition. Photograph magnification 40x.



D: Pollen grains of wheat flower at M_3 in late seeding heat stress condition. Photograph magnification 40x.

Plate 8. Comparison among micronutrient treated and untreated microscopic flower Image in late seeding heat stress condition of BARI Gom 28 (A-D)

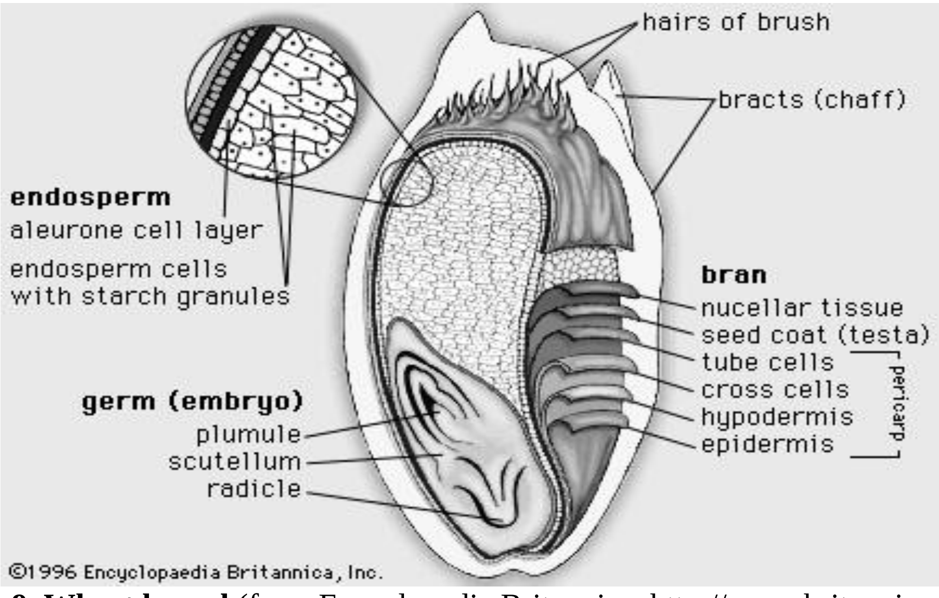


Plate 9. Wheat kernel (from Encyclopedia Britannica, http://www.britannica.com)