GROWTH AND YIELD OF WHEAT AS AFFECTED BY DIFFERENT AGRONOMIC MANAGEMENT PRACTICES

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CERTIFICATE

This is to certify that thesis entitled ***"GROWTH AND YIELD OF WHEAT AS AFFECTED BY DIFFERENT AGRONOMIC MANAGEMENT PRACTICES"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***AGRONOMY,*** *embodies the result of a piece of bona fide research work carried out by* ***AMALESH SARKER,*** *Registration No.* **13-05501** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

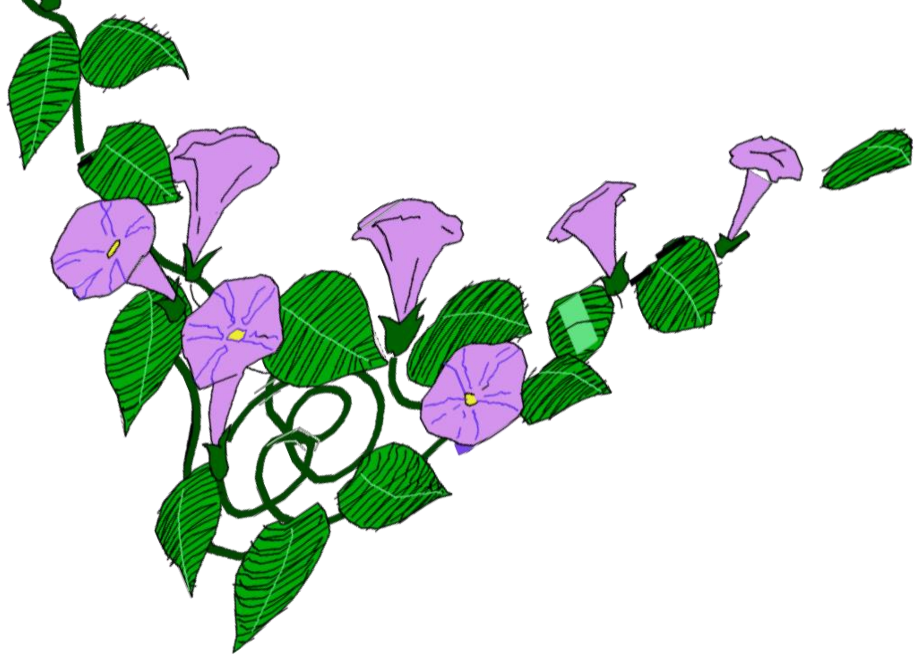
Place: *Dhaka, Bangladesh*

Prof. Dr. Parimal Kanti Biswas
Supervisor

Dedication

To my parents,
The reason of what I become today.
I am grateful for your great support
and continuous care.

To my youngest aunt,
The woman with whose blessing, I
started my journey.



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June, 2020 **The Author**

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ABSTRACT

A field experiment was carried out at Agronomy Research Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2018 to March 2019 to study the impact of different agronomic management practices on growth and yield of wheat. The experiment comprised of two factors having two varieties (BARI Gom-30 and BARI Gom-32) in the main plots and seven agronomic management practices (no management, no fertilizer, no weeding, no irrigation, no thinning, no pesticides and complete management) in the sub-plots. The experiment was laid out in split-plot design with three replications. Significant variation was recorded for fertilizer, weeding, irrigation, thinning and pest management on growth and different yield contributing characters and yield of wheat. The maximum plant height (71.98 cm), no. of tillers meter^{-1} (70.83), no. of leaves plant^{-1} (15.17), length of leaf (16.24 cm), breadth of leaf (1.46 cm), leaf area index (2.10), dry weight (108.59 g), SPAD value (46.63), length of flag leaf (16.54 cm), length of pedicel (16.67 cm), effective tiller number meter^{-1} (74.00), spike length (15.22 cm), no. of spikelets spike^{-1} (15.17), no. of grains spike^{-1} (40.33), 1000-grain weight (50.66 g), grain yield (1.78 t ha^{-1}), straw yield (2.14 t ha^{-1}), biological yield (3.92 t ha^{-1}), harvest index (45.40%) and shelling percentage (83.53%) were recorded from M_7 (complete management) and also maximum weed dry weight (43.05 g) and maturity days (107.17 days) were recorded from M_3 (no weeding) and M_6 (no pest management), respectively. While the minimum plant height (48.96 cm), no. of tillers meter^{-1} (40.33), no. of leaves plant^{-1} (7.33), length of leaf (8.14 cm), breadth of leaf (1.06 cm), leaf area index (0.19), dry weight (23.06 g), SPAD value (46.63), length of flag leaf (8.23 cm), length of pedicel (8.19 cm), effective tiller number meter^{-1} (39.00), spike length (10.87 cm), no. of spikelets spike^{-1} (8.50), no. of grains spike^{-1} (15.17), 1000-grain weight (36.73 g), grain yield (0.39 t ha^{-1}), straw yield (0.77 t ha^{-1}), biological yield (1.16 t ha^{-1}), harvest index (33.74%), dry weight of weed (4.27 g) and shelling percentage (76.08%) were recorded from M_1 (no management) and also minimum maturity duration (98.17 days) were recorded in M_4 (no irrigation). All the above-mentioned growth and yield contributing characters of wheat were found maximum in BARI Gom-30 compared to the BARI Gom-32 and further the higher plant height (76.01 cm), grain yield (1.88 t ha^{-1}), biological yield (4.10 t ha^{-1}), 1000-grain weight (51.40 g) and harvest index (45.87%) were recorded in V_1M_7 (BARI Gom-30 with complete management) compared to V_2M_7 (BARI Gom-32 with complete management). Irrespective of variety, no management practices reduced 78% grain yield of wheat that followed by 70% for no irrigation, 33% for no fertilizer, 19% for no weeding, 14% for no thinning and 10% for no pesticide application compared to complete management.

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LIST OF ABBREVIATIONS, ACRONYMS & SYMBOLS

%	Percent
@	At the rate
^{o}C	Degree Celsius
AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
CGR	Crop Growth Rate
CIMMYT	International Maize and Wheat Improvement Center
cm	Centimeter
CRI	Crown Root Initiation
CV (%)	Coefficient of Variance
DAA	Days After Anthesis
DAS	Days After Sowing
ET	Evapo-transpiration
et al.	And others
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization, Statistics Division
FYM	Farm Yard Manure
g	Gram
g m^{-2}	Gram per meter square
GCV	Genotypic Coefficient of Variation
HI	Harvest Index
K	Potassium
kg ha^{-1}	Kilogram per hectare
LAI	Leaf Area Index
LSD	Least Standard Deviation
m	Meter
m^{-2}	Square per meter

LIST OF ABBREVIATIONS, ACRONYMS & SYMBOLS (CONTD.)

m^3	Cube meter
mg ka^{-1}	Milligram per kilogram
mm	Millimeter
MoP	Muriate of Potash
MT	Metric tones
nos.	Number
N	Nitrogen
NAR	Net Assimilation Rate
NPK	Nitrogen, Phosphorous and Potassium
NUE	Nitrogen Use Efficiency
OECD	Organization for Economic Cooperation and Development
PCV	Phenotypic Coefficient of Variation
PFP	Partial Factor Productivity
RCBD	Randomized Complete Block Design
RGR	Relative Growth Rate
S	Sulphur
SAU	Sher-e-Bangla Agricultural University
SPAD	Soil-Plant Analyses Development
SRDI	Soil Resources Development Institute
t ha^{-1}	Tones per hectare
TDM	Total Dry Matter
TSP	Triple Super Phosphate
USG	Urea Super Granules
viz.	Namely
WUE	Water Use Efficiency

CHAPTER 1
INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important food grain and ranks first in terms of global consumption and production of food crop known as king of cereals (Costa *et al.*, 2013). It's the first cultivated food crops in the past 8000 years and still now it is used as one of the major cereal crops in Europe, West Asia and North Africa (Curtis, 2002). It belongs to the family Poaceae (Gramineae). The main cultivated species of wheat is *Triticum aestivum*. It is hexaploid and known as "common" or "bread" wheat (Shewry and Hey, 2015). Wheat is a widely adapted crop. It grows from temperate to cold region, irrigated to dry condition (Acevedo *et al.*, 2002). It is a staple food crop for about one billion people in as many as 43 countries and provides about 20 % of the total food calories. About two third of the total world's population consume wheat as staple food (Majumder,1991). It is rich in various nutrients compared to other food crops. Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006). In the world, it occupies around 219 million hectares of land and makes up 6% of the cereal production from 772 million tons with an average yield of 3.53 t ha^{-1} (FAOSTAT, 2017).

In Bangladesh, wheat ranks second position in respect of total area of land cultivated having an annual production of 1.35 million tons and total area of 0.44 million hectares (BBS, 2017). Wheat production in Bangladesh is lower than other wheat growing countries in the world due to various problems. But consumption rate of wheat is increasing day by day due to its low production cost, good market price and nutrition value. Agronomic management is an important tool for achieving the targeted yield. A good variety minus agronomic management can results zero yield. Hence agronomic managements are obligatory for higher yield and food security; of which balanced fertilization, weeding, irrigation, pest management are the major ones.

Integrated nutrient management determines sustainable soil fertility and productivity (Baruah and Baruah, 2015). Continuous crop cultivation without balanced fertilization is one of the major causes of soil degradation (Leite *et al*., 2011; Chouhan *et al*., 2015; Hossain *et al*., 2016). Application of farm manure for many times and during a long period improved crop production compared to those with no or low applications of fertilizers. In tropical regions continuous monoculture of cereals, using chemical fertilizers as main source of nutrients led to considerable decrease in yield after only a few years of cropping because of soil acidification and compaction. However, addition of organic inputs adequately improved physical, chemical and biological properties of these soils. Fertilizers when applied in time and according to the needs of the field, greatly improve per hectare yield of wheat (Zia *et al*., 1991). Therefore, the gap between realized and potential yield can be filled by collective use of suitable types of fertilizers, as appropriate combination of fertilizers can boost yield by almost 50%. Simultaneous increase occurs in the quality and yield with the increase of nitrogen fertilizer in winter wheat (Liu and Shin, 2013).

Weed competition has become a major constraint in limiting yield of any crop. Weeds compete with crop for space, light, moisture and nutrients and reduce the crop yield by 17 to 25% (Shad, 1987). Crop yield usually declines with increased weed intensity and interference duration and yield losses are more severe when resources are limited and weeds and crops emerge simultaneously (Zimdahl, 2007). Weed causes enormous losses to crop even more than other pests worldwide that on an average 37.3% of crop produce is damaged if weeds are not controlled in Bangladesh (Karim *et al*., 1998). Knowledge of weed interference has a vital role in forecasting yield losses by weed infestation and designing sustainable weed management systems (Fahad, 2014).

Water is essential at every stage of plant growth, from seed germination to plant maturation, but sensitivity of wheat to water stress increases as the plant growth progresses and reaches the maximum during early dough stage (Human *et al*., 1981). However, water stress during vegetative growth stages limits leaf and tiller development of winter wheat, while water stress during jointing increases ratio of senescence and decreases number of spikelets spike^{-1} (Musick and Dusek, 1980), while boot stage has been found to reduce grain yield (Hochman, 1982). Irrigation plays an imperative role for optimum growth and development of wheat. Grain yield and its components of wheat declined when exposed to drought stress condition (Fang *et al*., 2006).

Crop density is a key agronomical trait used to manage wheat crops and estimate yield. Plant population density may significantly impact on the competition among plants as well as with weeds and consequently affect the effective utilization of available resources including light, water and nutrients (Shrestha and Steward, 2003; Olsen *et al*., 2006). Crop density appears therefore as one of the important variables that drive the potential yield. This explains why this information is often used for the management of cultural practices (Godwin and Miller, 2003).

Diseases and insects have been common in winter wheat since it became a domestic crop. Diseases play an important role in lowering wheat yield in the global. In Bangladesh, the disease occurs in almost all wheat growing areas with varying degrees of severity, causing substantial loss in yield and seed quality (Rashid *et al*.,1994; Alam *et al*., 1994). In farmer field, the yield loss was estimated to be 14.97% due to no control of insects (Alam *et al.*, 1994). Foliar diseases reduce the wheat yield by 23-42% (Ahmed and Meisner, 1996). Sometimes, the disease causes 100% yield loss of wheat. The occurrence and severity of the disease are being increasing every year in Bangladesh (Alam *et al*., 1993). Knowing insects and diseases that may cause injuries and are likely to affect plant health and quality is critical to minimizing the gap between attainable yield and actual yield.

During the next three decades, the population of developing countries will grow by at least 1.6%. As this growing population becomes increasingly urban-based as incomes rise and as consumers substitute out of rice and coarse grain cereals, the demand for wheat will rise.

By 2020, two-thirds of the world’s wheat consumption will occur in developing countries (CIMMYT, 1997). To meet demand across the Asian Subcontinent, we will have to maintain wheat yield growth at 2.5% per year over the next 30 years, because cropped area is expected to remain minimal or even negative (Hobbs and Morris, 1996). Yield will not only have to grow; they will have to grow without depleting the natural resource base on which agriculture depends.

It is thus immense need to find out the individual influence of agronomic managements on growth and yield of wheat to sustain the food security of the country. Thus, the appropriate agronomic management practices need to be adopted by the farmers for maximizing wheat yield. Keeping in view the importance of wheat and role of agronomic managements, the present research work has been undertaken in rabi season with the following objectives:

i. To compare the performance of the two varieties of wheat.
ii. To compare the role of different agronomic management practices on yield reduction of wheat.
iii. To determine the interaction of variety and agronomic management practices on growth and yield of wheat.

CHAPTER 2
REVIEW OF LITERATURE

In this chapter a brief review of various researches that were conducted about different agronomic management practices and their influence on growth and yield of wheat have been included. An attempt is made to review the available literature those are related to the effect of agronomic management on the growth and yield of wheat. These reviews are the short summary of research works conducted in Bangladesh and other countries in the world.

2.1 Wheat

Stem of wheat is called culm and it is hollow in mature plant. It is cylindrical in shape and contains 3-6 nodes and internodes. Life duration is usually 100-120 days though it varies from variety to variety and weather condition. Wheat can grow under a wide range of climate and soil condition; however, it grows well in clayey loam soils and requires dry weather and bright sunlight. In Bangladesh, it is a rabi crop and requires 40-110 cm rainfall (Banglapedia, 2014).

Although wheat is an ancient domesticated crop in Indian subcontinent it was started to cultivate in 1930-1931. It was regarded as a food crop around 1942-1943 (Banglapedia, 2014). About 4% of total cropped area is occupied by wheat and 11% cropping area is occupied during rabi season. After the liberation war in 1971, different natural hazards occurred in Bangladesh, also population growth rate was higher (Hugo, 2006). In that circumstance, it was clear that only rice was not enough to meet the huge amount of food of the country (Banglapedia, 2006). Moreover, from 1971 to 1975 rice price was higher in the world market (OECD, 2008) and in Bangladesh production was decreasing due to various kind of natural disasters (Index Mundi, 2012). At that time, wheat gained its popularity as an alternative crop of cereals.

In Bangladesh, wheat is in second position among cereal food crops. During 1970, local variety “KHERI”, IP-52, IP-125 were cultivated. After then “KALYANSONA” and “SONALIKA” these two high yielding varieties were imported from abroad. Day by day its production is increasing. After 1998 (SOURAV) to present (BARI Gom-33), about 30 existing varieties are cultivated in the whole country. At present BARI Gom-25, BARI Gom-26, BARI Gom-27, BARI Gom-28, BARI Gom-29, BARI Gom-30, BARI Gom-31, BARI Gom-32 and BARI Gom-33 are widely cultivated varieties in Bangladesh.

Now-a-days, production of wheat is decreasing due to various kinds of natural disasters, pest and disease, competition with other rabi crops etc. There are many reports about various types of reason that are the main cause of wheat yield reduction. Among these reasons, agronomic managements like irrigation, fertilization, weeding, thinning and pest managements are most important. However, researcher efforts still continued to develop high-yielding varieties.

2.2 Effects of variety on growth and yield contributing characters

Shabi *et al.* (2018) showed that wheat varieties varied widely in their weed competitiveness and yielding ability. Grain yield ranged between 1.9 t ha^{-1} (BARI Gom-23) and 3.7 t ha^{-1} (BARI Gom-24) under weed-free condition and between 1.3 t ha^{-1} (BARI Gom-21) and 2.9 t ha^{-1} (BARI Gom-28) under weedy condition. Weed inflicted relative yield loss ranged from 17.8 to 51.2% among the varieties. Although BARI Gom-24 was the highest yielder but its competitive ability against weed was very poor. On the other hand, BARI Gom-28 and BARI Gom-30 appeared as the most weed competitive varieties (17.8 and 24.9% relative yield losses, respectively) with moderate grain yield. BARI Gom-30 was the best in terms of yield, but BARI Gom-28 ranked first in terms of weed competitiveness.

Din *et al.* (2018) laid out an experiment and showed the existence of adequate genetic variability among the tested wheat genotypes. High PCV and GCV were found in grains $spike^{-1}$, while highest broad sense heritability with inferior genetic advance was recorded for plant height. Wheat genotype PR-110 performed for grain yield, while PR-103 exhibited higher biological yield. The highest number of productive tillers m^{-2} was counted for PR-111, while intense leaf area index was displayed by PR-103. Hybrid-404 had relatively higher grains $spike^{-1}$ while PR-114 was observed for highest 1000-grain weight. Among the genotypes, Pirsabak-08 excelled for dwarf traits, while Hybrid-403 was found early maturing genotypes. Grain yield was positively correlated with productive tillers m^{-2} and biological yield. Genotypes PR-110 and Hybrid-404 resulted in superior grain yield among the genotypes.

Mahmud (2017) recorded data for weed severity, different yield contributing characters and yield of *Aus* rice. The lowest weed population and weed dry weight was recorded in M_4 (recommended management) and M_2 (no fertilizer application), respectively, whereas the highest weed population was found in the M_0 but the highest dry weight in M_1 treatment. The taller plant, grain yield (0.96 t ha^{-1}) and straw yield (2.75 t ha^{-1}) were recorded from V_2 compared to that of V_1. Similarly, the tallest plant, grain yield and straw yield were observed from M_4. In respect of interaction, the highest grain yield (2.43 t ha^{-1}) and straw yield (5.31 t ha^{-1}) were observed from V_1M_4, while the lowest grain yield (0.12 t ha^{-1}) from V_1M_0 and straw yield (0.85 t ha^{-1}) from $V_2 M_0$. Irrespective of variety, no management reduced 94-95% grain yield of *Aus* rice that was 84-89% for no weeding and no fertilizer application.

Azad *et al*. (2017) described the BARI released wheat varieties. They observed about BARI Gom-30 and BARI Gom-32 growth and yield parameters. BARI Gom-30 possessed these characters- tiller no. (4-6) $plant^{-1}$, plant height (95-100 cm), maturity days (100-105), spike comparatively longer, grains $spike^{-1}$ (45-50), 1000-grain weight (44-48 g), late variety, blast resistance, yield (4.5 to 5.5 t ha^{-1}), at seedling stage plant semi-erect, leaf deep green, flag leaf broader and looping.

BARI Gom-32 possessed following these characters- late sowing variety, tiller no (4-6) plant^{-1}, plant height (90-95 cm), leaf wider and deep green, maturity days (95-105), spike longer and no. of grain spike^{-1} (50-58), leaf blast and rust resistant, yield (4.6-5.0 t ha^{-1}).

Kamrozzaman *et al*. (2016) evaluated five wheat varieties against arsenic contaminated soils and determined accumulation of arsenic in grain and straw of wheat varieties. BARI Gom-21, BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were used as treatment variables. Result revealed that, wheat varieties differed in their grain arsenic concentration (0.49-1.15 mg kg^{-1}). The variety BARI Gom-26 was found to accumulate least arsenic in grains followed by BARI Gom-25 and BARI Gom-24 the highest under same growing condition due to phytoextraction potential of the varieties. Maximum grain yield (4.36 t ha^{-1}) was obtained from BARI Gom-26 followed by BARI Gom-25 and the lowest yield (3.43 t ha^{-1}) was recorded from BARI Gom-23.

Das (2016) conducted an experiment with two factors; Variety (3) viz. BARI mash-3 (V_1), BARI mash-2 (V_2) and BINA mash-1(V_3) and 3 management packages. The highest emergence percentage (33.44%), plant height (53.54 cm), number of leaflet plant^{-1} (19.89), dry weight (8.95 g plant^{-1}), branches plant^{-1} (2.22), 1000-seed weight (33.74 g) and seed weight (0.58 t ha^{-1}) was found from BARI mash-2. The management packages resulted highest emergence percentage (41.11%), plant height (79.39 cm), leaflet plant^{-1} (52.13), dry weight plant^{-1} (8.95 g), branches plant^{-1} (3.00) and seed yield (0.63 t ha^{-1}) from high management (M_3). The highest leaflet plant^{-1} (56.8 cm) was revealed in V_2M_3, and the highest seed yield (1.06 t ha^{-1}) and higher harvest index (49.75) was obtained from V_2M_3.

Al-Musa *et al*. (2012) studied the performance of some BARI wheat varieties. Four wheat varieties viz. BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were planted to evaluate their comparative performance in respect of germination percentage, growth, yield and yield contributing characters. Among the four varieties, BARI Gom-26 showed superior performance irrespective of all parameters studied except total dry matter content (TDM) and yield reduction percentage. Among the BARI varieties, BARI Gom-26 produced greater germination (61.00%) at 13 days judge against to other varieties. The taller plant (47.91 cm), higher LAI (1.84), maximum TDM (17.37 g plant^{-1}) and effective tillers hill^{-1} (18.08) were also obtained with the similar variety. BARI Gom-26 was also most effective to produce the maximum grains spike^{-1} (38.52), higher weight of 1000-grains (49.38 g), higher grain (3.35 t ha^{-1}) and straw (8.50 g plant^{-1}) yield and greater HI (4.03%).

Ali *et al.* (2011) carried out a field study to determine the influence of varying nitrogen levels (0, 70, 140 and 210 kg ha^{-1}) applied to wheat cultivar i.e. lnqilab-91 and Bakhar-2000. Data for various growth and yield parameter of the crops were collected and analyzed. Bakhar-2000 produced significantly more and taller plants throughout the crop growth stages and each increment of nitrogen increased plant height significantly.

Significantly higher number of tillers and fertile tillers was recorded in Bakhar-2000 and nitrogen applied at the rate of 210 kg ha^{-1}. This cultivar produced higher 1000-grain weight as well as grain yield than that of Inqlab-91.

Irfan *et al*. (2005) worked with four wheat genotypes viz. CT-0231, CT-99187, Bakhawar-092 and Saleem-2000 to test their performance against heat stress. The influence of heat stress was studied on yield and some other agronomic characters viz, days to 50% emergence, days to 50% heading, days to 50% maturity, plant height (cm), biological yield, grain yield, harvest index (%) and lodging percentage. All the parameters were varied from genotype to genotype.

2.3 Agronomic managements

Appropriate agronomic management practices greatly influenced on the growth and yield of wheat. Growth and yield of wheat was hampered due to improper weeding, thinning, irrigation schedule, fertilization and pest managements. Therefore, these managements were a complete package for satisfactory of any crop production specially wheat production in Bangladesh. Weed free condition during the critical period of competition, proper plant population maintaining, recommended dose of fertilizer application, controlling of insect-diseases and appropriate amount of water are essential for obtaining optimum growth and yield of wheat. Thus, the appropriate agronomic management practices need to be adopted by the farmers for maximizing yield of wheat.

2.3.1 Effects of fertilizer on growth and yield contributing characters of wheat

Mohan *et al.* (2018) carried out an experiment at Agronomy Research Farms, The University of Agriculture, Peshawar during 2015-16. They concluded that integrated nitrogen application (50% FYM + 50% urea) has delayed number of days to anthesis (123 days) and maturity (150 days) in wheat crop and showed maximum plant height (87.58 cm), grains $spike^{-1}$ (50 grains), thousand grains weight (39.24 g), grain yield (3146 kg ha^{-1}) and harvest index (38.05%). They also found that the treatment of integrated nitrogen application (50% FYM + 50% urea) showed significantly lowest weeds density (32 weeds m^{-1}) and minimum weeds dry weight (4.36 g m^{-2}).

Kumar *et al*. (2018) performed a research on effect of integrated nutrient management on yield and yield attributes and economics of wheat (*Triticum aestivum* L.) during rabi seasons of 2011-2012 and 2012-2013 at Hisar, Haryana. *Azotobacter* ST3 and Pseudomonas P36 + vermicompost @5 t ha^{-1} and minimum in no inoculation treatment during 2011-12 and 2012-13. They gave their opinion that application of 125% RDF, being statistically at par with 100% RDF, produced significantly higher number of effective tillers m^{-2}, grains $spike^{-1}$, grain, straw and biological yields (q ha^{-1}) than 75% RDF during 2011-12 and 2012-13. Test weight (g) and harvest index (%) did not differ significantly under quality of irrigation water levels of fertilizer and inoculation and vermicompost treatments during both the years.

Arif *et al*. (2017) conducted an experiment to evaluate different levels of potassium and zinc fertilizers on the growth and yield of wheat. Maximum plant height (91.13 cm), number of fertile tillers per square meter (309.71), spike length (14.01 cm), number of spikelets spike^{-1} (16.66), grains spike^{-1} (66.77), thousand grain weight (45.32 g), biological yield of 10190 kg ha^{-1}, grain yield 4535.8 kg ha^{-1} and harvest index (46.09%) and minimum plant height (64.55 cm), number of fertile tillers per square meter (196.58), spike length (8.16 cm), number of spikelets spike^{-1} (8.16), number of grains spike^{-1} (31.78), 1000-grain weight (28.06 g), biological yield (7205 kg ha^{-1}), grain yield of 2878 kg ha^{-1} and harvest index (39.91%) were recorded from the plots fertilized with 375 kg ha^{-1} potassium and 5 kg ha^{-1} zinc than from control plots. They concluded that application of potassium fertilizer (375 kg ha^{-1}) and zinc (15 kg ha^{-1}) significantly improved the growth and yield parameters of wheat.

Klikocka *et al*. (2016) conducted a study to evaluate the effect of nitrogen (N) and sulfur (S) fertilizer on grain yield of spring wheat and its technological quality. The experiment included 2 factors: N fertilization and S fertilization. The experiment showed that S fertilization increased grain yield by 3.58%. S had also positive influence on growth parameters like plant height, tiller number, dry matter production. Grains panicle^{-1} and 1000-grain weight were also increased significantly by S fertilization at 50 kg ha^{-1}. Positive correlation was found between the content of S in grain and grain yield (r = 0.73).

Singh *et al.* (2015) conducted an experiment to evaluate the effect of zinc levels and methods of application of boron on the growth, yield and protein content of wheat (*Triticum aestivum* L.). The treatments comprised three levels of zinc (0, 3.5 and 7 kg ha^{-1}) through zinc sulphate and four methods of application of boron (0, soil application @ 0.5 kg ha^{-1}, foliar spray @ 0.5kg ha^{-1} at 45 and 60 days after sowing and soil application @ 0.25 kg ha^{-1} + foliar spray @ 0.25 kg ha^{-1} at 45, 60 DAS. On the basis of the findings of the experiment, zinc @ 7 kg ha^{-1}, soil application of boron @ 0.25 kg ha^{-1} + foliar application of boron @ 0.25 kg ha^{-1} and their combination (i.e., 7 kg ha^{-1} zinc + soil application of boron @ 0.25 kg ha^{-1} + foliar application of boron @ 0.25 kg ha^{-1}) was found superior over all other treatments in relation to plant height, dry weight, effective tillers yield and yield attributes and protein content in grains of wheat.

Hayat *et al*. (2015) set an experiment and observed that applications of 140 kg N ha^{-1} at sowing alongside applications of 20 kg S ha^{-1} at anthesis was helpful in increasing 1000-grain weight and grain yields in wheat varieties. It was therefore recommended that foliar S should be included as an important input, alongside N in the production technology of wheat crop.

Zahoor (2014) conducted an experiment on effect of integrated use of urea and Farm Yard Manure (FYM) on Nitrogen uptake and yield of wheat (*Triticum aestivum* L.) in the experimental research farm agricultural university, Peshawar during December 2009 to May 2010. He showed that application of 10 tons FYM ha^{-1} before sowing increased the number of spikes m^{-2}, grain yield, grains $spike^{-1}$, 1000-grain weight compared to control. It was proved from the experimental results that the uses of FYM with urea before sowing have the potential to enhance the yield of wheat.

Khan *et al.* (2014) studied on the impact of Nitrogen (N) and Potash (K) levels and application methods on yield and yield attributes of wheat was investigated in experiments conducted at the University of Agriculture, Peshawar during Rabi 2010-11 and 2011-12. They were observed that as an average of the two years, grain yield increased by 7.6% with 15% foliar application of nutrients as compared with soil applied. Yield components improved with increase in N and K levels. Based on the average of the two years, N @ 180 kg ha^{-1} in interaction with K @ 90 kg ha^{-1} enhanced grain yield by (47.4%), biological yield (28.5%), 1000-grain weight (29.2%), and grains $spike^{-1}$ (24.6%) as compared with control. On the basis of these results, it was recommended that N @ 180 and K @ 90 kg ha^{-1} in combination should be applied for higher grain yield of wheat. Nitrogen @ 180 kg ha^{-1} with 10% foliar application are recommended for higher grain yield of wheat.

Nadim *et al.* (2013**)** conducted an experiment to 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) were assigned to sub-plots. The results revealed that different micronutrients significantly interacted with the application methods for physiological and agronomic traits including Leaf Area Index (LAI), Crop Growth Rate (CGR), Net Assimilation Rate (NAR) 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.

Asif *et al*. (2012) conducted a field experiment to study the effect of different levels of irrigation and nitrogen on growth and irrigation use efficiency of wheat crop. The results exhibited that the Crop growth rate (g m^{-2} d^{-1}), Leaf area index, number of fertile tiller $unit^{-1}$ area, Number of grains $spike^{-1}$ and Harvest index (%) were significantly increased by increasing the number of irrigation and nitrogen levels. Among irrigation levels, highest value (37.34%) for harvest index was achieved in treatment 4 (irrigation at tillering + booting + anthesis + milking + dough) and the highest value for harvest index (36.35%) was recorded for treatment N_2 (150 kg N ha^{-1}).

Ahmad and Irshad (2011) carried out an experiment on the effect of B application time on the yield of wheat, rice and cotton crop in Pakistan. The results revealed that B application at sowing time to wheat increased significantly the number of tillers $plant^{-1}$ (15%), number of grains $spike^{-1}$ (11%), 1000-grain weight (7%) and grain yield (10%) over control.

Among the treatments, B application at sowing time showed the best results followed by B application at the 1st irrigation and at booting stage.

Gul *et al*. (2011) designed an experimental trial to quantify the response of yield and yield component of wheat toward foliar spray of nitrogen, potassium and zinc. Yield and yield component of wheat showed significant response towards foliar spray of Nitrogen (N), Potassium (K) and Zinc (Zn). Maximum biological yield (8999 kg ha^{-1}), number of grains (52) $spike^{-1}$ and straw yield (6074 kg ha^{-1}) were produced in plots under the effect of foliar spray of 0.5% N + 0.5% K + 0.5% Zn solution (once), while control (no spray) plots produced minimum biological yield (5447 kg ha^{-1}), number of grains (29) $spike^{-1}$ and straw yield (3997 kg ha^{-1}). Similarly, maximum thousand grain weight (46 g) and grain yield (2950 kg ha^{-1}) were recorded in plots sprayed with 0.5% N + 0.5% K + 0.5% Zn solution (twice), followed by lowest values (36 g) and (1450 kg ha^{-1}) in plots having no spray (control). Among the treatment of 0.5% N + 0.5% K + 0.5% Zn solution applied either one or two times, gave best response towards yield and yield components of wheat in irrigated area of Peshawar valley.

Islam *et al.* (2011) conducted a field experiment to find out the effect of appropriate dose of Urea Super Granule (USG) on growth and yield of wheat. They found that plant height differed significantly due to variation in USG levels. Among the USG treatments, the tallest plant (95.77 cm) was recorded in BARI recommended dose applied as USG and the shortest plant (87.49 cm) was found than in control. The highest grain yield was recorded in 75% nitrogen of BARI recommended dose applied as USG (2.42 t ha^{-1}) and the lowest grain yield was recorded in no nitrogen (1.25 t ha^{-1}) where the second highest (2.28 t ha^{-1}) was recorded in 100% nitrogen of BARI recommended dose applied as USG. The highest straw yield (4.06 t ha^{-1}) was obtained from 100% nitrogen of BARI recommended dose applied as USG, which was statistically identical with 75% nitrogen of BARI recommended dose applied as USG (4.03 t ha^{-1}). Significantly the lowest straw yield (2.69 t ha^{-1}) was obtained in no nitrogen.

Ashraf *et al*. (2011) successfully did a research and gave their opinion that N as urea and P as single super phosphate resulted better length of spike, spikelet $spike^{-1}$, grains $spike^{-1}$, seed index values and yield of wheat ha^{-1}.

Kulczycki (2010) carried a field experiment to study the effect of sulfur fertilization on the yield and chemical composition of winter wheat. Elemental sulfur was applied through soil and foliar application. The soil applied sulfur significantly increased grain yield and also straw yield with a dose of 80 kg S ha^{-1}. Fertilizing with elemental sulfur significantly increased the overall sulfur content during the wheat vegetation when the highest doses were used. Tiller number, panicle length, 1000 grain weight were also obtained as highest with a dose of 80 kg S ha^{-1}.

Malghani *et al.* (2010) conducted a field experiment to investigate the combined effect of NPK (Nitrogen, Phosphorus and Potash) on the growth and yield of wheat cultivars Sahar-2006. The thrice replicated treatments F_0: 0-0-0 (NPK), F_1: 75-50-25(NPK), F_2: 100-75-50 (NPK), F_3: 125-100-75 (NPK), F_4: 150-125-100 (NPK), F_5: 175-150-125 (NPK) and F_6: 200-150-125 (NPK) kg ha^{-1}. They revealed that maximum growth parameters responded significantly to NPK fertilizers. They also concluded that highest grain yield of 5168 kg ha^{-1} was recorded with the application of 175-150-125 NPK kg ha^{-1}. The increase in yield was 51.58% higher as compared to control (2502 kg ha^{-1}), where no fertilizer was used.

Sultana (2009) conducted a field experiment to find out the effect of nitrogen level and weeding on the performance of wheat. The treatments comprised five different levels of Nitrogen (N) (0 kg ha^{-1}, 69 kg ha^{-1}, 92 kg ha^{-1}, 115 kg ha^{-1} and 138 kg ha^{-1}) and three weeding (no weeding, one weeding at 30 days after sowing and two weeding at 30 and 60 days after sowing). She showed that increasing nitrogen level upto 115 kg ha^{-1} and increasing number weeding increased grain yield by increasing all the yield contributing parameters. Interaction of 115 kg ha^{-1} and two weeding gave the highest values.

Bazzaz *et al*. (2008) conducted a field experiment at Gazipur during November, 2003 to March, 2004. The experiment was aimed at evaluating the effect of nitrogen and boron fertilizers on growth dynamics, dry matter production and yield in wheat. The experiment was designed in split-plot with three replications. Four nitrogen levels 0, 60, 120 and 180 kg ha^{-1} were assigned in main plots and four levels of boron 0, 0.5, 1 and 1.5 kg ha^{-1} was in sub-plots. Application up to 120 kg N ha^{-1} and 1.0 kg B ha^{-1} significantly increased the dry matter production, Leaf Area Index (LAI) and crop growth rate. The relative growth rate as well as net assimilation rate also responded well each 120 kg ha^{-1} and 1.0 kg 13 ha^{-1} of nitrogen and boron, respectively. The highest grain yield was reported with 120 kg N ha^{-1} and 1 kg B ha^{-1} because most of the yield contributing attributes yielded higher with this rate.

Rahman (2005) carried out an experiment to evaluate the effect of nitrogen sulfur and boron fertilizers on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. He reported that length of spike was significantly increased with the application of nitrogen at 125 kg ha^{-1}. He also observed that there was no significant response of different levels of nitrogen in case of number of effective spikelets $spike^{-1}$.

Singh (2005) plotted a field laboratory experiment and he documented that 120:60:40 kg NPK ha^{-1} application were a significant increase in term of grain and straw yield as well as improvement in protein content of wheat.

Hameed *et al.* (2003) conducted an experiment at Malakandher Research Farms NWFP Agricultural University Peshawar, Pakistan during 2000 to study the effect of different planting dates, seed rates and nitrogen levels on wheat variety. Plots treated with 160 kg N ha^{-1} recorded maximum days to emergence, emergence m^{-2}, tillers m^{-2}, days to maturity, plant height and grain yield. They also observed that application of 180 kg N ha^{-1} resulted into maximum number of tillers m^{-2} (369.0) and also observed that increasing nitrogen application increases the number of tillers m^{-2}.

An experiment was carried out by Matsi *et al*. (2003) on effect of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics and gave their opinion that gradual release of N from FYM has profoundly delayed crop maturity.

Deldon (2001) conducted an experiment with three N levels: no N (N_1), cattle (*Bos taurus*) slurry (N_2), and cattle slurry supplemented by mineral N fertilizers (N_3). Estimated available N from the soil (0-0.9 m) plus added fertilizer was 80 (N_1), 150 (N_2), and 320 (N_3) kg ha^{-1} for potato and 115 (N_1), 160 (N_2), and 230 (N_3) kg ha^{-1} for wheat. He reported that integrated nitrogen fertilizer has increased vegetative growth and resulted in delayed maturity of wheat crop.

2.3.2 Effects of weeding on growth and yield attributing characters of wheat

Bekele *et al.* (2018) found that the production of more total tillers at weed free plot might be attributed to better access of space, nutrient, water and light that enabled plants to produce more tillers m^{-2} and reduction in tiller number m^{-2} was probably the increased weed population and continuous competition reduced access to different resources. Ineffective weed management is considered as the main factor for low yield of wheat resulting in yield loss of up to 72.87% when there is uninterrupted weed growth.

Santosh *et al*. (2018) reported that a weed is important biological factor in crop production that cause yield reduction and it contributes around 45% of crop yield loss. Weeds deplete Photosynthetically Active Radiation by shading of lower leaves. It was predicated that 19 to 25 percent yield loss was observed due to 44 to 56 percent shading of the crop by the weeds.

Sateesh *et al*. (2018) conducted an experiment and found that grain yield of wheat was influenced significantly by weed control measure. It indicates that controlling weeds resulted in significant increase in grain yield compared to weed check. The increase ranged from 24.4% under hand weeding at 30 days and 50 DAS to 44.5% under weed free conditions.

Kaur *et al.* (2018) conducted a field experiment with 8 treatments viz, Weed-free, Weedy check, Pendimethalin 2.5 L ha^{-1}, Pendimethalin 3.75 L ha^{-1}, Clodinofop 400 g ha^{-1}, Sulfosulfuron 32.5 g ha^{-1}, Pinoxaden 1000 ml ha^{-1}, Atlantis 400 g ha^{-1} and replicated thrice. Results revealed that Pendimethalin (3.75 L ha^{-1}) was found effective to control weed population and produced higher number of effective tillers, 1000 grain weight and enhanced the yield up to 43.1% over weedy check. The higher grain and straw yield were recorded with application of pendimethalin @ 3.75 L ha^{-1} (5.19 and 8.29 t ha^{-1}, respectively). On the other hand, lower grain and straw yield was recorded with weedy check (3.63 and 6.77 t ha^{-1}, respectively) owing to severe crop weed competition which resulted in reduction in the expression of yield components such as effective tillers m^{-2} (347.2).

Salahuddin *et al*. (2016) reported that the competition among weeds and wheat plant enforced to grew plant. The increased plant height with the weedy plot might be due to the effect of severe competition among plants which make them elongated in search of light and lack of availability of plentiful of growth encouraging factors in weedy plot that allowed the plants to increase in height, the competition between weeds and crop for sun light and space in un-weeded plots resulted in tall height of plants. They also reported that the maximum spike length was recorded at complete weed free, whereas minimum spike length was recorded in weedy check. The increment of spike length might be due to sufficient growth resources facilitated cell elongation for spike length per plant for weed free plots.

Tesfaye *et al.* (2014) commented that apart from increasing the production cost, weeds also intensify the disease and insect pest problem by serving as alternative hosts and uncontrolled weed growth throughout the crop growth caused a yield reduction of 57.6 to 73.2%.

A field experiment was conducted by Mustari *et al.* (2014) and found that Carfentrazone-ethyl + Isoproteuron also contributed to the highest grain yield of 3.56 t ha^{-1} with the highest Harvest Index (HI) of 40.42%. Carfentrazone-ethyl + Isoproteuron accompanied by one hand weeding also contributed to statistically identical grain yield of 3.33 t ha^{-1}. Single ingredient Carfentrazone-ethyl alone and when accompanied with one hand weeding also contributed to statistically similar grain yields of 3.26 t ha^{-1} and 3.46 t ha^{-1}, respectively. The study revealed that, combined ingredient herbicide Carfentrazone-ethyl + Isoproteuron as well as Carfentrazone-ethyl alone might use at field level due to their better weed control efficiency, favorable effect on crop growth and development and higher grain yield.

Singh (2014) conducted a field experiment to find out the performance of different herbicides and in this trial the use of pendimethalin @1000 g ai. proved best for wheat field, which may have exerted a positive effect on wheat yield as compared to other herbicides as noticed at harvesting. Metribuzin @ 250 g ai. proved least effective herbicide from the point of view of wheat growth and yield. Hence, metsulfuron methyl, 2,4-D and clodinafop were not so effective as compared to pendimethalin for wheat.

The medium dose recorded 91.34% and 65.97% increase in grain and straw yield respectively as compared to other two doses. However, again pendimethalin recorded maximum grain yield with 45.05% followed by metsulfuron and 2,4-D with 24.22% and 8.31% respectively.

According to Hakim *et al*. (2013) the chlorophyll content (SPAD value) was decreased with increasing the duration of weed interference period. The maximum chlorophyll content (42.10) was observed in the season-long weed-free treatment followed by 75 day weed-free and 30 days weedy treatments (>41) while the minimum chlorophyll content was found in the season-long weedy treatments. At 4 dS m^{-1}, the maximum value was recorded in the season-long weed-free and 15 days weedy treatments with >40, while the minimum value was found in season-long weedy treatments.

Sultana *et al.* (2012) conducted an experiment to evaluate the effect of variety and weeding regime on yield and yield wheat. The longest plant (101.59 cm) was obtained from the weed free treatment, which was statistically similar with one hand weeding treatment. The shortest plant (95.40 cm) was recorded in no weeding (control treatment) treatment, number of effective tillers $plant^{-1}$ (4.95) was observed in weed free treatment followed by two hand weeding treatment (4.49) and the lowest number of fertile tillers $plant^{-1}$ (3.27), effective tillers m^{-2} (246.70) was with W_2 (Two weeding at 30 and 60 DAS) and the lowest spikes m^{-2} (185.40), highest number of spikelets $spike^{-1}$ (39.19) was with W_2 (Two weeding at 30 and 60 DAS) and the lowest number of spikelets spike-1(25.81), highest 1000-grain weight was measured in weed free treatment whereas the lowest (47.30 g), highest grain yield (5.09 t ha^{-1}) was obtained from weed free treatment followed by two hand weeding treatment (4.89 t ha^{-1}). The lowest grain yield (4.13 t ha^{-1}) and maximum straw yield (7.67 t ha^{-1}) was measured by weed free treatment and the lowest straw yield (6.45 t ha^{-1}) was produced by no weeding treatment.

Zahoor *et al*. (2012) found that the mean for different treatments differed significantly for biological yield. Among different application rates, the highest biological yield of 7.2 t ha^{-1} was recorded with the application of Buctril super at 0.45 kg ha^{-1} and the lowest biological yield (6.88 t ha^{-1}) was recorded in weedy plots. They indicated that the highest grain yield of 2678 kg ha^{-1} was recorded with the application of Buctril super 0.45 kg ha^{-1}.

Acker (2010) carried out an experiment to assess the effect of weed management practices on yield attributes and yield of wheat. The result indicated that higher weeding frequency increased plant height by 20-30%, dry matter accumulation of wheat increased by 12-20%, the grains $spike^{-1}$ increased by 8-12% and the yield increase was 4.48 and 8.52% higher compared to no weed control treatments.

Sultana (2009) proposed that weeding operation had significant effect on plant height of wheat. However, the longest plant height (89.96 cm) at harvest was with W_2 (Two weeding at 30 and 60 DAS) and the minimum (87.76 cm), longest spike (10.29 cm) was with W_2 (Two weeding at 30 and 60 DAS) and the shortest spike length (9.45 cm), highest number of filled grains spike^{-1}(32.94) was with W_2 (Two weeding at 30 and 60 DAS) where the lowest (23.98), the highest 1000-grains weight (45.44 g), highest grain yield (3.74 t ha^{-1}) was with W_2 (Two weeding at 30 and 60 DAS). On the other hand, the lowest grain yield (2.57 t ha^{-1}) was with treatment W_2 (Two weeding at 30 and 60 DAS) and the lowest 1000-grains weight (43.21 g), highest straw yield (5.02 t ha^{-1}) at harvest was with W_2 (Two weeding at 30 and 60 DAS) and the lowest straw yield (4.83 t ha^{-1}), highest harvest index (42.19%) was with W_2 (Two weeding at 30 and 60 DAS) and the lowest harvest index (34.15%) and highest values of dry weight plant^{-1} (4.60, 9.06, 14.06 and 16.99 g at 30, 60, 90 DAS and at harvest, respectively) and the lowest dry weight plant^{-1} (3.84, 7.16, 10.77 and 13.60 at 30, 60, 90 DAS and at harvest, respectively) were observed from no weeding (W_0) treatment.

Ullah (2009) and Bibi (2004) reported less population of weeds from hand weeding followed by Affinity application and maximum plant height from application of herbicide and hand weeding at early growth stages.

Chaudhary *et al*. (2008) reported that critical period of weeds-crop competition is between 30 to 50 days after crop sowing. They reported maximum grains spike^{-1} in plots where weeds were controlled at early growth stage of wheat crop. Delayed weeding practices indicated low yield because critical period of weeds-crop competition was 30 to 50 days after crop sowing. Riaz *et al*. (2006) reported that hand weeding and herbicide application at appropriate time can considerably increase plant height.

Hossain (2008) carried out a field trial and observed that weed controlling has a significant effect on growth and yield of wheat. He mentioned that the highest number of tillers plant^{-1} (2.52. 5.89. 6.01 and 6.10), the highest spike lengths (7.25, 12.12 and 12.47 cm), highest values of spikelet spike^{-1} (5.98 and 6.08) and the highest harvest index (46.69%) were shown by Sencor 70WG @ 0.40 kg ha^{-1} at 30, 60, 90 DAS and at harvest respectively than control plots (no weed control).

Sujoy *et al.* (2006) conducted a field experiment to assess different weed management practices in wheat. They reported that hand weeding at 21 and 35 Days After Sowing (DAS) was effective in controlling the weeds in the field. And it produced the highest number of filled grains spike^{-1}, highest values of grain yield, highest straw yield, highest biological yield and highest harvest index compared to other weed control treatments.

Field trial was carried out at Ranchi (Jharkhand) in India on sandy clay loam soil by Singh and Saha (2001).They found that pendimethalin @ 1 kg ha^{-1} pre-emergence, isoproturon @ 1.5 kg ha^{-1} post-emergence, 2,4-D @ 1.5 kg ha^{-1} post-emergence, combination of pendimethalin 0.5 kg ha^{-1} pre-emergence + isoproturon 1 kg ha^{-1} post-emergence and pendimethalin 0.5 kg ha^{-1} pre-emergence + 2,4-D 1 kg ha^{-1} post-emergence recorded significantly taller plants, greater number of effective tillers and fertile spikelet as compared to weedy check. Similarly, Yadav *et al*. (2001) reported that application of pendimethalin @ 2.0 kg ha^{-1} pre-emergence recorded significantly higher number of tillers $plant^{-1}$, grains ear^{-1} and test weight over weedy control.

2.3.3 Effects of irrigation on growth and yield attributing characters of wheat

Islam *et al.* (2018) performed an experiment on effects of different irrigation levels on the performance of wheat and they found that the tallest plant (76.86 cm), maximum requiring days to anthesis (61.00 days), maturity (109.0 days) and maximum number of effective tillers (5.00 $hill^{-1}$), the highest grain growth (3.11 g at 36 DAA) and grains (44.00 $spike^{-1}$) were obtained with three irrigation (T_3) levels. Similarly, T_3 further showed the greater performance on spike length (17.28 cm), 1000-seed weight (50.16 g), grain yield (4.16 t ha^{-1}), straw yield (5.89 t ha^{-1}) and biological yield (10.05 t ha^{-1}) as well as the higher harvest index (41.39%). Investigated above whole characters were produced lower performances under no moisture (irrigation) treatments.

Latif *et al*. (2016) found that water tension during the vegetative growth phase led to reduced plant height due to the impact of water tension in the cell division and cell elongation. The average yield of wheat is quite low in such areas which is mainly due to shortage of water. Water stress not only affects the morphology but also severely affects the metabolism of the plant. The extent of modification depends upon the cultivar, growth stage, duration and intensity of stress.

Irrigation is positively related with growth and yield of wheat. Appropriate irrigation increases the growth and grain yield of wheat and vise-versa. Uddin *et al.* (2016) and Islam *et al*. (2016) reported that about 30% of wheat production is lost due to lack of irrigation water and 40% yield loss due to lack of nutrient supply and metal contents in soil as well as their availabilities, pollution status of other environmental parameters in the country.

Abdul-Jabbar *et al.* (2016) evaluated that the decrease in the elongation phase is due to the fact that the water stress reduced the number of spikes per square meter, the number of grains per spike and the weight of the grain, because at this stage the development of the branches bearing. Spike is determined as well as the emergence and development of the seedlings. The water pressure can also reduce the number of grains in the spike.

Uddin *et al.* (2016) and Ahmed (2006) recorded that enough irrigation water and nutrient supply can increase yield up to 70% in our country. Irrigation frequency has a significant influence on the growth and yield of wheat. With the increase of irrigation frequencies, the grain yield of wheat can be increased. Proper time of irrigation especially in crown root initiation stage is very important for successful growth of wheat and it has a great impact on higher grain yield.

Chouhan *et al*. (2015) observed that water saving of about 28.42% higher when drip irrigation was applied rather than the border irrigation system. They also stated that water productivity of drip irrigated wheat was 24.24% higher compared with the border irrigated wheat. But there was a slightly reduction of 10.80% in the grain yield because of severe water deficit during the growing stages.

Islam *et al*. (2015) carried out an experiment with four irrigation stages viz. I_0: No irrigation; I_1: Irrigation at crown root initiation (CRI) stage (18 DAS); I_2: Irrigation at pre-flowering stage (45 DAS) and I_3: Irrigation at both CRI and pre-flowering stage. Maximum number of tillers hill^{-1} (5.2), CGR (6.7 gm^{-2} day^{-1}), RGR (0.03 gm^{-2} day^{-1}), dry matter content (28.7 g), number of spikes hill^{-1} (4.5), number of spikelets spike^{-1} (19.0), ear length (17.5), filled grains spike^{-1} (30.8), total grains spike^{-1} (32.9), weight of 1000-grains weight (47.1 g), grain yield (3.9 t ha^{-1}), straw yield (4.9 t ha^{-1}), biological yield (8.8 t ha-^{1}) and harvest index (45.9%) were obtained from I_3 whereas lowest occurred in I_0. They also stated that early flowering (70.6 days), maturity (107.2 days) and minimum number of unfilled grains spike^{-1} (2.1) were also obtained from I_3.

Mueen-ud-din *et al*. (2015) conducted an experiment and declared that maximum grain yield (4232.5 kg ha^{-1}), no. of grains spike^{-1} (51), 1000-grain weight (46.5 g) were observed due to application of 3 acres inch water and highest water use efficiency of 20, 19.89 kg ha^{-1}/mm was obtained where 2 acres inch water was given.

Atikullah (2014) showed that maximum dry matter content (18.8 g plant^{-1}), Crop Growth Rate (CGR) (13.5 gm^{-2} day^{-1}), Relative Growth Rate (RGR) (0.024 gm^{-2} day^{-1}) were obtained from I_1 which was statistically same as I_2 whereas lowest obtained from I_0. They also reported that plant height (80.7 cm), number of tiller (4.9 hill^{-1}), number of spikes (4.7 hill^{-1}), number of spikelets (18.5 spike^{-1}), spike length (19.2 cm), filled grains (29.3 spike^{-1}), total grains (31.3 spike^{-1}), 1000-grains weight (44.4 g), yield (grain 3.4 t ha^{-1}, straw 5.7 t ha^{-1} and biological 9.1 t ha^{-1}) and harvest index were observed better in $I_{1.}$

The findings of Ngwako and Mashiqa (2013) that the irrigation significantly affected days to maturity, number of tillers, number of grains per spike and grain yield. Irrigation throughout the growth stages increased number of tillers, number of grains spike^{-1}, grain yield, harvest index and grain protein by 20.58%, 26.07%, 42.72%, 16.71% and 3.31% respectively over no irrigation.

Onyibe (2005) reported that increase in irrigation regime however increased days of maturity. They also found that irrigation throughout the growth stages effect on grain yield. Similarly, Mubeen *et al*. (2013) also reported that irrigation at tillering, stem elongation stage, booting and grain filling stage recorded the higher yield of wheat.

Wang *et al.* (2012) reported that a significant irrigation effect was observed on grain yield, kernel numbers and straw yield. The highest levels were achieved with a high irrigation supply, although Water Use Efficiency (WUE) generally decreased linearly with increasing seasonal irrigation rates in 2 years. The low irrigation treatment (0.6 ET) produced significantly lower grain yield (20.7%), kernels number (9.3%) and straw yield (12.2%) compared to high irrigation treatment (1.0 ET). The low irrigation treatment had a higher WUE (4.25 kgha^{-1} mm^{-1}) rather than that of 3.25 kgha^{-1} mm^{-1} with high irrigation over the 2 years.

Taipodia and Singh (2013) reported that 1000-grain weight was significantly affected by different irrigation levels, where 6 irrigations obtained the higher weight of 1000-seed.

Wu *et al*. (2011) revealed that the effect of compensation irrigation on the yield and water use efficiency of winter wheat and found that the effect of irrigation on plant height, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better. The wheat yield was increased by 2.54% - 13.61% compared to control and the treatments, irrigation of 900 m^3 ha^{-1} at the elongation stage and of 450 m^3 ha^{-1} at the booting stage or separate irrigation of 900 m^3 ha^{-1} at the two stage were the highest.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during rabi seasons. The I_2 treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. Progressive increase in number of irrigations from 1 to 4 increased various yield contributing characters viz., effective tillers m^{-2}, ear length, no. of grains ear^{-1} and test weight while three and four irrigations were found statistically as par with each other.

Maqsood *et al*. (2010) observed that three irrigations at critical growth stages provided the maximum number of productive tillers, number of grains per spike, 1000-grain weight and grain yield.

Hira (2009) was carried out an experiment to investigate the performance of wheat as affected by different of irrigation and nitrogen level during the winter season of 2009-2010. When the plant characters- plant height and spike length were highest with 161 kg N ha^{-1}, the yield and yield contributing characters- number of productive tillers $plant^{-1}$, number of effective spikes m^{-2}, dry weight of plant, number of spikelet $spike^{-1}$, number of grains $spike^{-1}$, weight of 1000-seeds, grain yield, straw yield and harvest index were highest with 115 kg N ha^{-1}. Significantly, highest yield of wheat was obtained when irrigation was applied 3 times at CRI, maximum tillering, grain filling stage along with the recommended nitrogen dose of 115 kg ha^{-1}.

Kabir *et al.* (2009) showed that the highest plant height (82.33 cm), spike length (8.37 cm), filled grain $spike^{-1}$ (31.90), effective tillers $plant^{-1}$ (3.31), grain yield (3.30 t ha^{-1}), straw yield (4.09 t ha^{-1}), biological yield (7.39 t ha^{-1}) and harvest index (44.47%) were obtained from single irrigation applied at CRI stage.

Ali and Amin (2007) carried out an experiment with irrigation treatments were given as: no irrigation, control (T_0); one irrigation at 21 DAS (T_1); two irrigations at 21 and 45 DAS (T_2); three irrigations at 21, 45 and 60 DAS (T_3); and four irrigation at 21, 45, 60 and 75 DAS (T_4). Plant height, number of effective tillers $hill^{-1}$, spike length, number of spikelets $spike^{-1}$, filled grains $spike^{-1}$ obtained significantly by applying irrigation at different levels. The growth, yield attributes and yield of wheat increased significantly when two irrigations were given at 21 and 45 DAS over the other treatments.

Gupta *et al*. (2001) observed that number of tillers decreased to a greater extent when water stress was imposed at the anthesis stage while imposition of water stress at booting stage caused a greater reduction in number of tillers. Among the yield attributes number of tillers were positively correlated with grain and biological yield irrigation at the anthesis stage. Grain yield and biological yield decreased to a greater extent when water stress was imposed at the anthesis stage and at the booting stage whereas leaf area and shoot dry weight significantly correlated with grain and biological yield at both the stages.

2.3.4 Effects of thinning on growth and yield attributing characters of wheat

Yang *et al.* (2019) studied to evaluate the growth of wheat tillers and plant nitrogen-use efficiency (NUE) will gradually deteriorate in response to high plant density and over-application of N. A 2-year field study was conducted with three levels of plant densities and three levels of N application rates to determine how to optimize plant density and N application to regulate tiller growth. The two years results suggested that increasing the plant density (from 75×104 plants ha^{-1} to 336×104 plants ha^{-1}) in conjunction with the application of 290 kg N ha^{-1}. N will maximize grain yield, and also increase PFP_N (39.7 kg ha^{-1}), compared with the application of 360 kg N ha^{-1}.

Increasing plant density is one of the most efficient ways of increasing wheat (*Triticum aestivum* L.) grain production. However, overly dense plant populations have an increased risk of lodging. Results showed that decreasing plant density enhanced culm quality, as revealed by increased culm diameter, wall thickness and dry weight per unit length (Zheng *et al*., 2017).

Li *et al*. (2016) explored that the grain number and grain weight vary significantly at different spikelet and grain positions among wheat cultivars grown at different plant densities. In this study, two winter wheat (*Triticum aestivum* L.) cultivars, 'Wennong6' and 'Jimai20', were grown under four different plant densities for two seasons, in order to study the effect of plant density on the grain number and grain weight at different spikelet and grain positions.

External factors including light, plant density and fertilizer application have a significant effect on the growth of tillers, whereas increasing planting density from 135 to 405 plants m^{-2} has been shown to significantly increase grain yield (Dai *et al*., 2014). Although further increases in density do not affect grain yield. Increasing the seeding rate has been found to increase the proportion of yield obtained from the main spike and decreases the proportion from high-position tiller spikes.

Although low plant density produces a higher grain number and grain weight $spike^{-1}$, this is generally not sufficient to compensate for the lower spike density m^{-2} generated by a lower tiller density. The optimal density for wheat cultivation, but the results vary based on the experimental conditions and tested parameters. In wheat, the number of spikelets $spike^{-1}$ changes under different planting densities. However, some studies have reported that dense planting does not necessarily increase the grain yield (Gendua *et al*., 2009).

Plant density is an important factor that influences the growth and yield in wheat (Hiltbrunner *et al*., 2007; Murty and Murty, 1982 and Grassini *et al*., 2011). In this study, Grain Number (GN) and Grain Weight (GW) reduced with the increasing plant density. Li *et al*. (2016) and Xu *et al.* (2015) reported that under dense planting, the grain number at the 3^{rd} and 4^{th} grain positions and the 1^{st} and 2^{nd} grain positions of the basal and top spikelet decreased.

Roy (2007) a field experiment was conducted to find out the influence of sowing depth and population density on growth and yield of wheat. The experiment was carried out with three replications having three sowing depths viz. 2 cm, 4 cm and 6 cm in main plot and 6 population densities viz. 100 seeds m^{-2}, 200 seeds m^{-2}, 300 seeds m^{-2}, 400 seeds m^{-2}, 500 seeds m^{-2} and 600 seeds m^{-2} in the sub plot. Highest grain yield (3.36 t ha^{-1}) was also produced from 300 seeds m^{-2} treatment, whereas, 100 seeds m^{-2} treatment produced the lowest grain yield (2.29 t ha^{-1}). The highest straw yield was observed with 400 seeds m^{-2} and the lowest from 100 seeds m^{-2}. The highest harvest index was recorded with 100 seeds m^{-2}. Among the interaction treatments, the sowing depth of 2 cm and 300 seeds m^{-2} produced the highest grain yield of 3.72 t ha^{-1}.

In favorable environments, there is a uniform yield due to regular tiller formation and to the distribution of photosynthesis products which contribute to grain yield (Rickman *et al.,* 1983). On the other hand, tiller development in stress conditions is irregular, forming a high rate of underdeveloped or weak tillers which compete with normal tillers and affect plant grain yields (Martin, 1987). Also, adjusting seeding density to environmental (favorable or unfavorable) conditions adequate the level of competition between tillers, especially around tillering initiation.

2.3.5 Effects of pesticides on growth and yield attributing characters of wheat

Begum *et al.* (2017) conducted an experiment to find out the influence of infected seed and plant population density on the spread of leaf blight and yield of wheat. Population density and seed infection levels had significant influence on plant growth parameters and yield and yield contributing character of wheat cv. Shatabdi. Population density 300 seeds m^{-2} showed best performance in case of grain and straw yield. The highest grain yield (2.64 t ha^{-1}) and straw yield (6.87 t ha^{-1}) was obtained from 300 seeds m^{-2} population density. The Highest grain yield (3.14 t ha^{-1}) was also produced from 0% seed infection treatment, whereas, 45.10% to 60% seed infection treatment produced the lowest grain yield (1.04 t ha^{-1}). The highest straw yield was observed with 300 seeds m^{-2} and the lowest from 200 seeds m^{-2}.

Fengqi *et al.* (2013) stated that the english grain aphid (*Sitobion avenae* F.) was a destructive insect pest of wheat. In this study, wheat germplasm was evaluated for resistance and tolerance to english grain aphid infestation. Except for spikelets number $spike^{-1}$, 1000-kernels weight, spike length, grain weight $spike^{-1}$, and sterile spikelets number $spike^{-1}$ of infested plants were all significantly impacted by english grain aphid infestation.

Duyn (2005) reported that there are three primary species of aphids found in NC wheat; the English grain aphid, bird-oat cherry aphid, and corn leaf aphid. He also reported that cereal leaf beetle has one generation each year and both the adult and larval stages eat leaf tissue on wheat and oats. Yield reductions of 10% to 20% are typical in infested commercial fields by cereal leaf beetle.

Larsson (2005) revealed that thrips larvae and adults cause partial or complete coloration of the ears, known as the white ear effect, drying of the flag leaf, partial ear fertilization, and incomplete grain filling. Grain weight losses is about 5-7% in mildly damaged grain, but can reach 15-31% or more in severely damaged grain.

The flag leaf contributes 60 to 85% to the final grain yield. Yield reduction results if even 5 to 10% of the flag leaf surface is diseased, yield is reduced 0.5 bu/A (Oplinger and Wersman, 1985).

CHAPTER 3
MATERIALS AND METHODS

The experiment was conducted during the period from November, 2018 to April, 2019 to study the growth and yield of wheat as affected by different agronomic management practices. This chapter composes of a brief description on experimental site, climate and weather, soil, land preparation, layout, experimental design, intercultural operations, data recording procedure and their analyses. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 23º 74´N latitude and 90º 35´E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.1.2 Soil

The soil belongs to “The Madhupur Tract”, AEZ- 28 (FAO, 1988). The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The land was above flood level and sufficient sunshine was available during the experimental period. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix II.

3.1.3 Climate and weather

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*., 1979). Occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March) was visible. The annual precipitation of the site was around 2200 mm and potential evapotranspiration was 1300 mm.

The average maximum temperature was 30.34^{o} C and average minimum temperature was 21.21^{o} C. The average mean temperature was 25.17^{o} C. The experiment was done during the rabi season. Temperature during the cropping period ranged between 12.7^{o} C to 29.6^{o} C. The humidity varies from 55% to 79%. The day length was 10.5-11.0 hours only and there was partial rainfall from the beginning of the experiment to during harvesting. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment was presented in Appendix III.

3.2 Materials

3.2.1 Plant materials

In this experiment, two wheat varieties BARI Gom-30 and BARI Gom-32 were used. These varieties were released in 2014 and 2017, respectively. BARI Gom-30 was developed by crossing BAW-677 and Bijoy (BARI Gom-23).

Characteristics of BARI Gom-30

Plant height: 95-100 cm

Duration: 100-105 days

Grain no. spike^{-1}: 45-50

1000-grain weight: 44-48 g

Seed: white, shiny and medium in size

Yield: 4.5-5.5 t ha^{-1}

This variety is of short duration and resistant to high temperature, leaf spot and rust, and blast disease of wheat. It takes 57-62 days to spike initiation.

Characteristics of BARI Gom-32

Plant height: 90-95 cm

Duration: 95-105 days

Grain no. spike^{-1}: 42-47

1000-grain weight: 50-58 g

Seed: white amber in color and large in size

Yield: 4.6-5.0 t ha^{-1}

This variety is high yielding, early in maturity and tolerant to terminal heat stress. It is resistant to leaf rust and *Bipolaris* leaf blight and also shows tolerant to wheat blast disease.

3.2.2 Fertilizer doses

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), Gypsum, Zinc sulphate and Boric acid were used in the experimental land as a source of nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), sulfur (S), zinc (Zn) and boron (B), respectively. The recommended doses of these fertilizers for wheat cultivation were 120, 70, 65, 20, 5 and 1 kg ha^{-1} as a form of N, P_2O_5, K_2O, S, Zn and B, respectively. (Krishi Projukti Hatboi, 2017).

3.2.3 Treatments: The experiment comprises of two factors.

Factor A: Variety

i. BARI Gom-30 – V_1
ii. BARI Gom-32 – V_2

Factor B: Agronomic Management

i. Control (no management) – M_1
ii. No fertilizer but all other managements – M_2
iii. No weeding but all other managements – M_3
iv. No irrigation but all other managements – M_4
v. No thinning but all other managements – M_5
vi. No pesticides but all other managements – M_6
vii. Complete management (recommended) – M_7

As such there were 14 (2×7) treatment combinations viz. V_1M_1 , V_1M_2, V_1M_3, V_1M_4, V_1M_5, V_1M_6, V_1M_7, V_2M_1, V_2M_2, V_2M_3, V_2M_4, V_2M_5, V_2M_6 and V_2M_7.

3.2.4 Design and layout of the experiment

Plot no.	: 43
Land area	: 270 m^2
Experimental design	: Split-plot design
No. of replications	: 03
Total no. of plots	: 42
Plot size	: (3.50 m×1.20 m) = 4.20 m^2
Duration of experiment	: November, 2018 – April, 2019
Seed rate	: 140 kg ha^{-1}
No. of rows $plot^{-1}$	: 06 nos.

3.3 Crop husbandry

3.3.1 Seed collection

The seeds of both varieties viz. BARI Gom-30 and BARI Gom-32 were collected from Wheat Research Division at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.3.2 Preparation of the experimental land

The land was first ploughed on 26 October, 2018 by tractor. The land was then harrowed again on 6 and 7 November to bring the soil in a good tilth condition. The final land preparation was done on 10 November, 2018. The land was leveling and laddering, weeds and stubbles were removed from the field. The experiment was laid out on 12 November, 2018 according to the experimental design.

3.3.3 Sowing of seeds

Seeds were sown on 12 November, 2018 by hand and it was in line sowing method. When land was in proper "Joe" condition, furrows were made and watering was done in the line and wheat seeds were sown. Seeds were then covered properly with soil by hand. The line to line distance for wheat was 20 cm and continuous line was maintained for plant to plant.

3.4 Intercultural operations

Germination of seeds started at 3 days after sowing. After seed germination various kinds of intercultural operations were done viz. thinning, weeding, fertilization, irrigation, mulching and most importantly taking plant protection measures.

3.4.1 Application of fertilizers plot^{-1}

All fertilizer and manure except urea were applied at basal dose during final land preparation. Urea fertilizer was applied at three installments. First portion was applied at basal dose with other fertilizers, second was given during CRI stage (20 DAS) and third was given before flowering stage (45 DAS). All fertilizers were applied per plot except control and no fertilizer treatment plots with previously mentioned recommended dose as 37×3 g (urea), 63 g (TSP), 46 g (MoP), 53 g (gypsum), 5 g (Zinc sulphate) and 3 g (Boric acid).

3.4.2 Gap filling and thinning

As germination was vigorous no need to gap filling but thinning operation of seedlings was done to maintain proper plant population at a row as per treatment. Thinning out was done for once. It was done at 20 days after sowing (DAS).

3.4.3 Weeding and mulching

There were so many weeds prominent in the research field like kakpaya ghash (*Dactyloctenium aegyptium* L.), Shama (*Echinocloa crussgalli*), Durba (*Cynodon dactylon*), Mutha (*Cyperus rotundus* L.) Bathua (*Chenopodium album*) Shaknatey (*Amaranthus viridis*), Foska begun (*Physalis beterophylls*), Titabegun (*Solanum torvum*), Shetlomi (*Gnaphalium luteolabum* L), Arail (*Leersia hexandra*) and so on. Weeding was done in two times. First was done at 20 DAS with thinning operation and second at 40 DAS as per treatment. Mulching was done during weeding time.

3.4.4 Irrigation

As some treatments were non-irrigated, hence irrigation was applied very carefully. The field was medium high land and dried rapidly that might to need many times of irrigation but three fundamental irrigations were maintained timely. First irrigation was given at CRI stage after weeding and thinning operation, second irrigation was given at 45 DAS or at flowering stage and third irrigation was given at grain development stage or 80 DAS. All the irrigations were applied to M_2, M_3, M_5, M_6 and M_7 treatments. As M_1 was fully controlled condition and M_4 was no irrigation, so irrigation was not applied to these plots except the sowing time.

3.4.5 Plant protection measures

Infestation of insect-pests was noticed during the growing period of wheat. While the plant was in seedling stage, field was infested by insect severely. At this moment, contact insecticide Ripcord 10 EC @ 25ml/10 L with water was applied in the all plots except fully controlled and no pest management plot by foliar spraying. When the plants were in full growing stage, the field was again infested by insects and insecticide Saifanon 57 EC @ 20ml/10 L with water was applied following experimental treatments i.e. no insecticides in M_1 and M_6 treatments.

The experimental plots were attacked by birds after full heading of spikes. So, watching net was installed over the experimental plots to control the birds. During the grain filling and development stage, severe infestation of rodents was observed in some plots and necessary control measures were taken.

3.5 General observation of the experimental plot

Except the regular intercultural operations, I also observed my research plot time to time to find out visual difference among the treatments and to protect plant from different types of insects, pests and diseases.

3.6 Harvesting and post-harvest operations

Synchronize maturity of wheat of all the plots didn't occur because of different types of agronomic management varied the maturity specially irrigation. Early maturity occurred in fully controlled and no irrigation plots due to water scarcity. These above mentioned two types plot were matured by only 98 days and all others were as usual.

Maturity of wheat was determined when 90% of the spikes became golden yellow color. First harvesting was done at 19 February, 2019; second and third harvesting were done at 27 February, 2019 and 02 March, 2019 respectively. Initially 10 spikes were collected from second line of both sides at the plot to find out no. of length of spike, spikelets spike^{-1} and also find out shelling percentage. Middle two lines were harvested carefully and separated. They were properly tagged and brought to the threshing floor for recording data. Before threshing plants were dried properly and then threshed by hand with the help of light hammer. The grains were cleaned and sun dried to reduce moisture content at 12%. Straw was also sun dried properly.

3.7 Data collection

Grain yield and straw yield data was collected from middle two lines of each plot. Two lines were collected separately and bundled with proper tagging. Then this yield was converted to t ha^{-1}. Growth parameters were collected at 25 cm of second line of every plot. Five plants were marked by binding rope to identify the same plants for data collection. Dry matter production data were collected from 25 cm length from second line of right side for three times at 30, 60 and 90 DAS.

3.7.1 Crop growth components

i. Plant population m^{-2}
ii. Plant height
iii. Number of tillers linear meter^{-1}
iv. Leaves number plant^{-1}
v. Length of leaf
vi. Breadth of leaf
vii. Leaf Area Index (LAI)
viii. Dry matter weight linear meter^{-1}
ix. SPAD value
x. Length of flag leaf
xi. Length of pedicel
xii. Maturity duration

3.7.2 Data regarding with weed

i. Dry weight of weed m^{-2}

3.7.3 Yield and yield contributing components

i. No. of effective tillers linear $meter^{-1}$
ii. Length of spike
iii. Number of spikelets $spike^{-1}$
iv. Number of grains $spike^{-1}$
v. Weight of 1000 grain
vi. Shelling percentage
vii. Grain yield
viii. Straw yield
ix. Biological yield
x. Harvest index

3.8 Data recording procedure

An outline of data recording procedure was given below:
Data were collected very carefully. Growth parameters and dry matter weight related harvesting or destructive harvesting were done with a regular interval. Crop growth characters were measured total four times; 20, 40, 80 DAS and finally during harvesting. Destructive harvest was done for three times at 30, 60 and 90 DAS.

3.9 Crop growth components

3.9.1 Plant population

The number of plant population was counted for two times; first one was done at 20 DAS and second at harvesting. Plant population data were collected from one $meter^2$ area by using a one $meter^2$ rectangle. During data collection, the metal rectangle was placed carefully at every plot so that seedlings didn't injure.

3.9.2 Plant height

The height of plant was recorded in centimeter (cm) at the time of 20, 40, 80 DAS and finally at harvest. Data were recorded of pre-selected same 5 plants from the inner rows of each plot. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of spike after heading. The collected data were finally averaged.

3.9.3 Number of tillers linear $meter^{-1}$

To count the number of tillers per linear meter, 25 cm row's tillers were counted and it converted into 100 cm or 1 linear meter. To identify the accurate number of tillers, firstly it was selected 25 cm of second row in every plot. Then the tiller number in that row's was counted at 20 DAS. During harvesting time, the tiller number was again counted.

3.9.4 Number of leaves plant^{-1}

During the data collection procedure, the leaves of each plant were counted. This was done for three times at 20, 40 and at last 80 DAS. Leaf number was counted for five plants then it was converted as average number leaves plant^{-1}.

3.9.5 Length of leaf

The length of leaf was measured with a meter scale from five pre-selected plants at 20, 40 and finally 80 DAS and the average value was recorded. The length of leaf was taken every time from middle aged leaves of plants.

3.9.6 Breadth of leaf

The breadth of leaf was measured with a small feet scale from five pre-selected plants at 20, 40 and finally 80 DAS and then it was calculated as average breadth of leaf. The breadth of leaf was taken on an average at the middle part of leaves.

3.9.7 Leaf area index

Leaf area index was estimated measuring the average length and breadth of leaf (at 20, 40 and 80 DAS) and multiplying by a factor of 0.75 followed by Yoshida (1981). Leaf Area Index (LAI) was calculated following the standard formula as mentioned below:

Leaf Area Index (LAI) = Leaf area (cm^2)/ Ground area (cm^2)

3.9.8 Dry matter weight linear meter^{-1}

Destructive harvesting was done for the measuring of dry matter weight per linear meter. For that, 25 cm row's plants were selected from the second line of every plot and then it was converted into one meter. All the plants were uprooted with hand hoe and washed with water to remove clinging soil. Oven drying at a temperature of 70 to 80^o C for 72 hours and weighing the samples with an electric balance were done carefully at the Central Laboratory, SAU, Dhaka. This was repeated for three times viz. 30, 60 and 90 DAS.

3.9.9 SPAD value

SPAD values of leaf were measured with the help of chlorophyll meter (SPAD-502 Plus). It's actually the measurement of chlorophyll content in the leaf. SPAD value reading was taken from the middle-aged leaf of five pre-selected plants and calculated as average SPAD value. This was done for two times at 40 and 70 days after sowing.

3.9.10 Length of flag leaf

After fully heading of spikes, the flag leaf of wheat was visible distinctly. The length of flag leaf was measured by a meter scale at 80 days after sowing. The data were collected from five pre-selected plants and calculated as average length of flag leaf.

3.9.11 Length of pedicel

After fully flowering, the growth of pedicel was ceased and the length of pedicel was taken at 80 days after sowing from five pre-selected plants. The length of pedicel was then calculated as average pedicel length.

3.9.12 Maturity duration

The data of crop maturity days were collected by visual inspection the plot frequently. When 90% or above spikes were matured, it was considered as maturity of wheat. Synchronize maturity of all the plots didn't occurred due to effect of different types of agronomic management.

3.10 Data regarding with weed

3.10.1 Dry weight of weed

The weeds from 25 cm^2 area of each plot were uprooted and washed with water to remove soil and then oven dried at 70 to 80^o C for 72 hours. The sample was then allowed to cool down to the room temperature and final weight of the samples was taken. The taken values were converted into 1 m^2 area multiplying by 4.

3.11 Crop yield and yield contributing components

3.11.1 No. of effective tiller linear meter^{-1}

The number of effective tillers was counted at linear 25 cm row with the help of a meter scale from individual plot and then the value was converted into one linear meter.

3.11.2 Length of spike

Spike length was measured in centimeter (cm) from ten plants at basal node of the rachis to apex of spike and then averaged. It was measured during harvesting time.

3.11.3 Number of spikelets spike^{-1}

Number of spikelets was counted from 10 spikes separately and averaged to determine the number of spikelets spike^{-1}.

3.11.4 Number of grains spike^{-1}

Number of grains was counted from 10 spikes. The 10 spikes were threshed separately and counted grains from individual spike and then calculated as average number of grains spike^{-1}.

3.11.5 1000-grain weight

One thousand seeds were counted randomly from properly cleaned and dried total harvested seeds of each individual plot and then weighed with a digital electric balance in grams and recorded.

3.11.6 Shelling percentage

Shelling percentage is the ratio of grain weight to chaff weight and grain weight. From every plot, 10 spikes were collected and sun-dried properly. After sun-drying, spikes were threshed and grain and chaff were kept separately for weighing. Then shelling percentage was calculated by the following formula:

$$\text{Shelling Percentage (\%)} = \frac{\text{Grain weight (g)}}{\text{Grain weight+Chaff weight (g)}} \times 100$$

3.11.7 Grain yield

Grain yield was determined from the central two lines of each plot. They were dried befittingly and threshed and grain and straw were separated. Then the grain was weighted ascertainably with a digital balance and expressed as t ha^{-1}.

3.11.8 Straw yield

Straw obtained from each plot were sun-dried properly and weighed carefully. The dry weight of straw of central two lines were harvested, threshed, dried and weighted with the help of an electric balance and finally converted to t ha^{-1} basis.

3.11.9 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the help of following formula:

Biological yield = Grain yield + Straw yield.

3.11.10 Harvest index

Harvest index is the ratio of grain yield to biological yield. Harvest index was calculated from the grain and straw yield of wheat from each plot and expressed in percentage by using following formula:

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

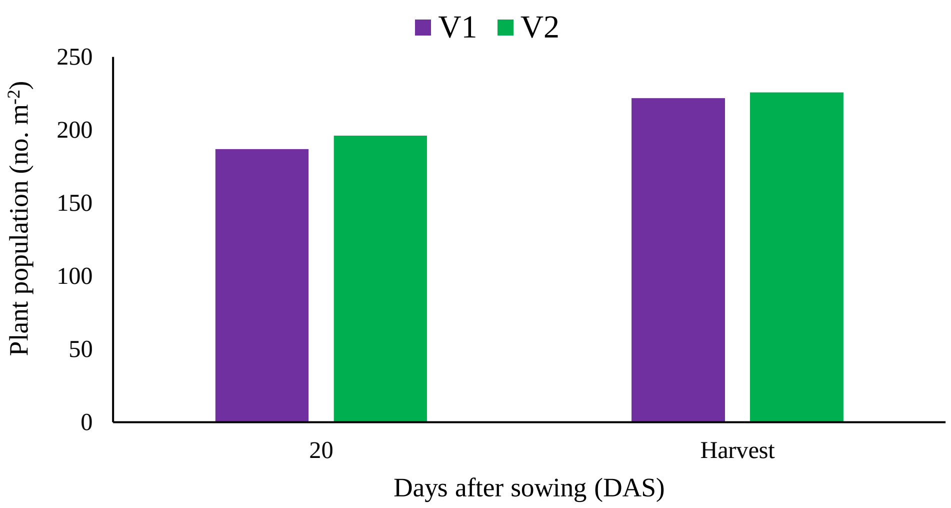
3.12 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program CropStat and the mean differences were arbitrated by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The experiment was conducted to study the effects of different agronomic management practices on the growth and yield of wheat. The analyses of variance (ANOVA) of the data on different growth, yield contributing components and yield of wheat are presented in Appendix IV-XVIII. The results have stated with the help of table and graphs and all possible interpretations are given under the following headings:

4.1 Crop growth components
4.1.1 Plant population m^{-2}
4.1.1.1 Effects of variety
Plant population is an important parameter of growth. Non-significant variation of plant population was observed between two varieties at 20 DAS and harvest (Appendix IV & Fig. 1). Same amount of seeds was used for both the varieties but BARI Gom-32 showed numerically higher population per unit area (196.10 m^{-2}) compared to that of BARI Gom-30 (186.90 m^{-2}) but they were statistically similar. At harvest, the variety also had a non-significant effect on the number of plant population per unit area. The variety BARI Gom-32 showed 4.92% higher plant population at 20 DAS that minimized by the other variety at harvest might be due to its higher tillering capacity of the variety BARI Gom-30. Azad *et al.* (2017) also assessed, BARI Gom-30 and BARI Gom-32 showed similar number of tillers (4-6) plant^{-1} that influenced the plant population meter^{-2} non-significantly.

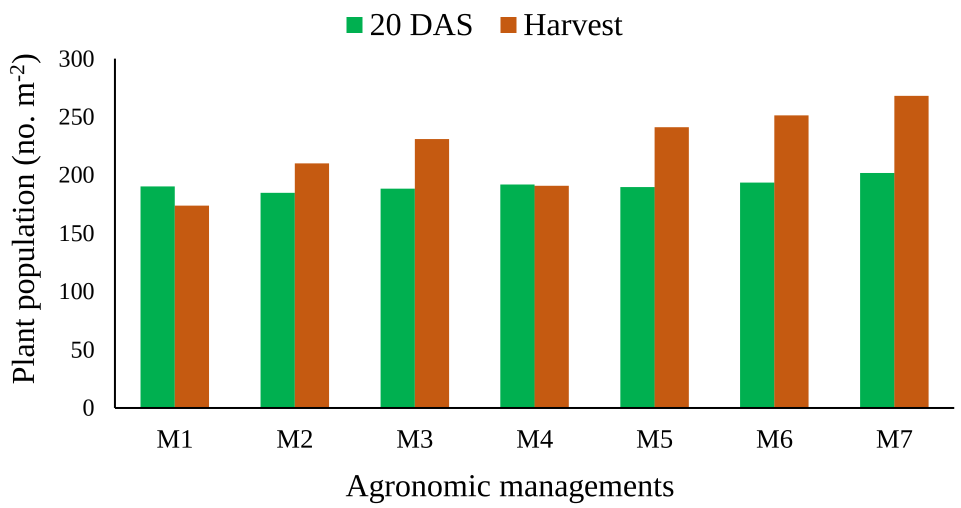


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 1. Effects of variety on plant population of wheat at different growth stages.

4.1.1.2 Effects of agronomic managements

Plant population was varied significantly by the effects of agronomic managements at different growth stages of wheat (Appendix IV & Fig. 2). At 20 DAS, the highest plant population per unit area (201.83) was counted in M_7 (complete management) which was statistically dissimilar to others and the second highest plant population (193.67) was recorded in M_6 (no pesticides) which was statistically similar to M_1, M_4 and M_5. While the lowest plant population (184.83) was found in M_2 plot which was statistically similar to M_3 (188.33) and also too M_5 (189.67). At this stage, all treatments showed numerically more or less same plant population per unit area but statistically significant.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 2. Effects of agronomic managements on plant population of wheat at different growth stages ($LSD_{(0.05)}$ = 5.065 and 10.348 at 20 DAS & harvest, respectively).

At harvest, the highest plant population (268.00) was observed in M_7 (complete management) which was statistically significant from other treatments. The second highest plant population (251.33) was counted from M_6 (no pesticides) which was statistically insignificant with M_5 (241.00). The M_6 treatment decreased plant population by 6.63% compared to M_7 for the reason of no pest management. The result was also supported the findings of Begum *et al.* (2017). The third highest plant population was recorded from M_3 (230.83) that was also statistically similar with M_5 and it decreased plant population by 16.10% compared to M_7 due to no weed management. On the other hand, the lowest plant population was recorded (173.67) in M_1 (control) that was statistically different from other treatments. The second lowest plant population was recorded from M_4 treatment (190.83) which was statistically dissimilar from others and decreased plant population by 40.44% compared to M_7 due to no irrigation applying.

The third lowest plant population (210.17) was enumerated from M_2 that was statistically different from other treatments and it decreased by 27.52% plant population compared to M_7 due to no fertilizer management. Grassini *et al.* (2011), Hiltbrunner *et al*. (2007) & Murty and Murty (1982) also mentioned plant density as an important factor that influences the growth parameters of wheat.

4.1.1.3 Interaction of variety and agronomic managements

Statistically significant variation of plant population of wheat was noticed at 20 DAS and harvest by the interaction of variety and agronomic managements (Appendix IV & Table 1). The maximum plant population at 20 DAS (207.33) was observed in V_2M_7 (BARI Gom-30 with complete management) which was statistically different from others.

Table 1. Interaction of variety and agronomic managements on plant population of wheat at different growth stages

Treatment combinations	Plant population (no. m^{-2}) at	
	20 DAS	Harvest
V_1M_1	183.33 fg	176.67 i
V_1M_2	180.33 h	202.67 fg
V_1M_3	186.00 fgh	229.00 de
V_1M_4	185.67 fg	184.00 hi
V_1M_5	188.33 fg	245.00 bc
V_1M_6	188.33 fg	245.67 bc
V_1M_7	196.33 b-e	269.33 a
V_2M_1	197.00 bcd	170.67 i
V_2M_2	189.33 ef	217.67 ef
V_2M_3	190.67 d	232.67 cd
V_2M_4	198.33 bc	197.67 gh
V_2M_5	191.00 d	237.00 cd
V_2M_6	199.00 b	257.00 ab
V_2M_7	207.33 a	266.67 a
$LSD_{(0.05)}$	7.163	14.613
CV (%)	2.22	3.88

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

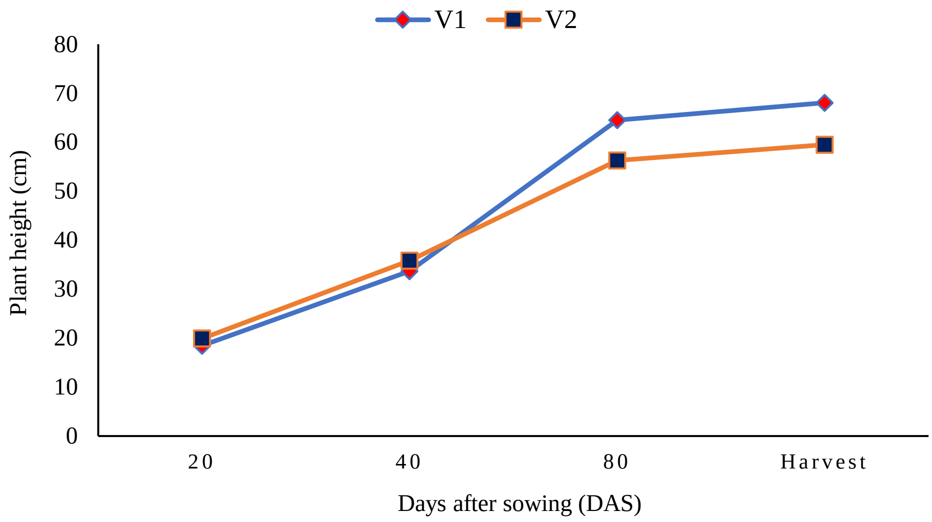
The second maximum plant population (199.00) was found in V_2M_6 that was statistically similar to V_1M_7, V_2M_1 and V_2M_4 and third maximum plant population (198.33) was recorded in V_2M_4 which was statistically insignificant with V_2M_1 and V_1M_7. While the minimum plant population (180.33) was observed in V_1M_2 which was statistically conforming to V_1M_3 (186.00). The second minimum plant population (183.33) was counted in V_1M_1 that was statistically similar to V_1M_4, V_1M_5 and V_1M_6 and also too V_1M_3.

At harvesting, plant population per unit area of wheat was also varied statistically by the interaction effects of variety and agronomic managements. The maximum plant population (269.33) was noted from V_1M_7 treatment which was statistically non-significant with V_2M_7 and V_2M_6. The second maximum plant population (245.67) was recorded in V_1M_6 which was statistically similar to V_1M_5 and also to V_2M_6. The third maximum plant population (237.00) was noticed in V_2M_5 which was statistically similar to V_2M_3 and also too V_1M_5 and V_1M_6. While the minimum plant population (170.67) was noted from V_2M_1 plot which was statistically similar to V_1M_1 and V_1M_4. The second minimum plant population (197.67) was recorded in V_2M_4 plot which was also statistically similar to V_1M_4. From the above discussion, findings concluded that at 20 DAS, BARI Gom-32 performed higher plant population per unit area compared to BARI Gom-30 with complete management but at harvest, BARI Gom-30 performed higher plant population per unit area compared to BARI Gom-32 with complete managements might be higher tillering capacity of variety BARI Gom-30. Similar assessment was also found by Bekele *et al.* (2018), Malghani *et al.* (2010) and Gupta *et al*. (2001).

4.1.2 Plant height

4.1.2.1 Effects of variety

Plant height is an important growth index of crop. Plant height was varied statistically at 80 DAS and harvest but non-significant effect was observed at 20 DAS and 40 DAS for varieties (Appendix V & Fig. 3). Plant height of BARI Gom-30 at 20 DAS and 40 DAS was lower than BARI Gom-32 which was statistically insignificant but at 80 DAS and harvest, BARI Gom-30 showed higher plant height compared to that of BARI Gom-32 might be due to its genotypic characters. Azad *et al.* (2017) reported that plant height of BARI Gom-30 is higher (95-100 cm) compared to BARI Gom-32 (90-95 cm). Similar result was also found by Kamrozzaman *et al*. (2016). They narrated that plant height was varied with variety to variety might be due to its genotypic characters.



V_1= BARI Gom-30 and V_2= BARI Gom-32

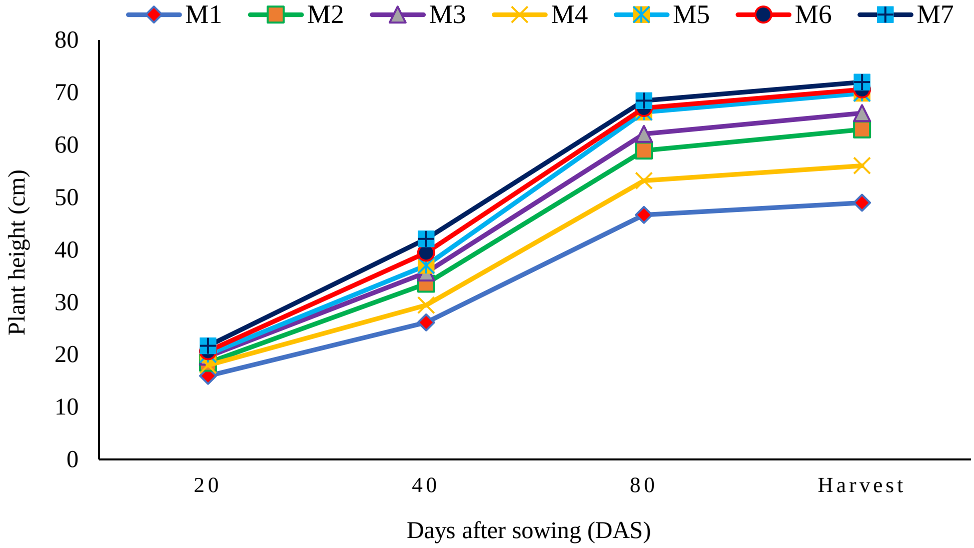
Figure 3. Effects of variety on plant height of wheat at different growth stages ($LSD_{(0.05)}$ = 4.537 and 5.466 at 80 DAS and harvesting, respectively).

4.1.2.2 Effects of agronomic managements

A statistically significant influence was noticed on plant height of wheat by the effects of agronomic managements at different growth stages (Appendix V & Fig. 4). At 20 DAS, the highest plant height (21.65 cm) was recorded in M_7 (complete management) which was statistically different from others. The second highest plant height (20.65 cm) was measured from M_6 that was statistically similar with M_5 (20.04 cm). The M_6 and M_5 treatments decreased plant height compared to M_7. Similar literary data was not found. While the lowest plant height (15.92 cm) was observed in M_1 (control) that was statistically significant from others. The second lowest plant height (17.95 cm) was found in M_4 (no irrigation) which was also statistically insignificant with M_2 (no fertilizer). The M_4 treatment reduced 20.61% plant height compared to M_7. The result was supported by the findings of Latif *et al.* (2016). Plant height was decreased by 17.41% in M_2 (No fertilizer) compared to M_7 (complete management). Mohan *et al.* (2018) and Arif *et al.* (2017) was also found similar results. The third lowest plant height (19.61 cm) recorded in M_3 which was also statistically similar to M_5. The M_3 plot showed 10.40% lower plant height compared to M_7. But finding was contrary to the findings of Salahuddin *et al.* (2016). They opinioned that increased plant height with the weed check plot might be due to the effect of severe competition among plants which make them elongated in search of light.

At 40 DAS, the highest plant height was determined in M_7 (42.09 cm) that was statistically significant from others. Second maximum plant height (39.45 cm) was recorded in M_6 (no pesticides) which was statistically different from other treatments. The third highest plant height (36.98 cm) was measured in M_5 which was statistically non-significant with M_3 (35.64 cm). Whereas the lowest plant height was found (26.14 cm) in M_1 (control) which was statistically dissimilar from others.

The second minimum plant height (29.41 cm) was noticed in M_4 (no irrigation) that was statistically significant from others. The M_4 treatment showed 43.11% lower plant height compared to M_7 for the reason of no irrigation. Similar result was also found by Atikullah (2014). Third minimum plant height was found out in M_2 (33.52 cm) which was statistically significant from others and it decreased plant height by 25.57% compared to M_7 due to no fertilizer applying. Klikocka *et al*. (2016) and Singh *et al.* (2015) was also found similar results.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 4. Effects of agronomic managements on plant height of wheat at different growth stages ($LSD_{(0.05)}$ = 1.168, 2.725, 2.039 and 2.091 at 20, 40, 80 DAS and harvest, respectively).

Statistically significant variation of plant height of wheat was also differed at 80 DAS. The highest plant height (68.42 cm) was recorded in M_7 (complete management) that was statistically non-significant with M_6 (67.03 cm) (no pesticides). The second highest plant height was recorded (66.23 cm) in M_5 (no thinning) which was also statistically similar to M_6. The third highest plant height (62.09 cm) was noted from M_3 that was statistically dissimilar from others and it decreased plant height by 10.19% compared to M_7 due to no weed management. Sultana *et al.* (2012) and Acker (2010) was also found similar results. On the other hand, the lowest plant height (46.67 cm) was found in M_1 (no management) that was statistically different from others. The second lowest plant height (53.16 cm) was found in M_4 which was statistically different from other treatments. The M_4 treatment reduced plant height by 28.71% compared to M_7 for the reason of no irrigation applying. Wu *et al*. (2011) was also found similar findings. The third lowest plant height was measured from M_2 (58.92 cm) that was statistically significant from others and it decreased plant height by 16.12% compared to M_7 due to no fertilizer apply.

The result also supported by the findings of Ali *et al.* (2011). Plant height was boosted up 40.60% due to agronomic managements compared to control at this growth stage.

At harvesting, plant height of wheat was varied numerically and statistically due to the influence of agronomic managements. Maximum plant height was measured (71.98 cm) in M_7 that was statistically insignificant with M_6 (no pesticides). The second maximum height was recorded in M_5 (69.84 cm) which was also statistically similar with M_6. The third maximum plant height (66.06 cm) was obtained from M_3 treatment which was statistically different from others and it decreased plant height by 8.96% compared to M_7 due to no weed management. Chaudhary *et al*. (2008), Ullah (2009) and Bibi (2004) also opined that weed infestation decreased plant height of crops. While minimum plant height (48.96 cm) was reported in M_1 (no management) that was statistically significant with other managements. The second minimum plant height (56.02 cm) was found in M_4 that was statistically dissimilar from others. The M_4 treatment showed 28.49% lower plant height compared to M_7 for the reason of no irrigation applying. Kabir *et al.* (2009) & Ali and Amin (2007) also observed similar results. The third minimum plant height was recorded from M_2 (62.94 cm) which was statistically different from others and it reduced plant height by 14.36% compared to M_7 due to no fertilizer apply. Islam *et al.* (2011) also assessed similar findings. Plant height was increased by 47.02% due to complete agronomic managements compared to no management.

4.1.2.3 Interaction of variety and agronomic managements

In all stages of wheat, the plant height showed significant variations due to the influence of variety and agronomic managements (Appendix V & Table 2). At 20 DAS, the tallest plant (22.53 cm) was found in V_2M_7 that was statistically non-significant with V_2M_6 (21.79 cm). The second tallest plant (21.05 cm) was recorded in V_2M_5 which was statistically similar with V_2M_3, V_1M_7 and V_2M_6. BARI Gom-32 with complete management performed higher plant height compared to BARI Gom-30 with complete managements. Whereas the shortest plant (15.51 cm) was found in V_1M_1 that was statistically similar to V_2M_1. The second shortest plant height (17.84 cm) was observed in V_1M_4 that was statistically V_1M_2. The remaining all other treatments performed numerically more or less same plant height but statistically significant.

At 40 DAS, the highest plant height was observed in V_2M_7 (43.32 cm) that statistically similar to M_1M_7 (40.87 cm). The second highest plant height (40.44 cm) was found in V_2M_6 that statistically similar with V_1M_6, V_2M_5 and V_1M_7. The third highest plant height was noted from V_2M_3 (36.37 cm) which was statistically insignificant with V_1M_5 and V_1M_6, V_2M_5 and V_2M_6. While the lowest plant height (24.67 cm) was recorded in V_1M_1 (no management) that was statistically insignificant with V_2M_1 (27.62 cm). The second lowest plant height (27.86 cm) was recorded from V_1M_4 that was also similar to V_2M_1. The third lowest plant height (30.96 cm) was obtained from V_2M_4 which was also statistically non-significant with V_1M_4.

Plant height was increased by 75.60% due to variety and complete agronomic managements compared to control management. The remaining all other treatments performed numerically more or less same plant height but statistically significant.

Table 2. Interaction of variety and agronomic managements on plant height of wheat at different growth stages

Treatment combinations	Plant height (cm) at			
	20 DAS	40 DAS	80 DAS	Harvest
V_1M_1	15.51 l	24.67 j	50.21 g	52.28 f
V_1M_2	18.03 g-k	32.76 fg	65.16 cd	70.03 bc
V_1M_3	18.51 f-i	34.91 def	66.67 c	71.21 b
V_1M_4	17.84 g-k	27.86 hi	54.47 ef	57.65 de
V_1M_5	19.03 g	36.10 cde	70.63 b	74.13 a
V_1M_6	19.52 f	38.45 bc	71.40 ab	75.04 a
V_1M_7	20.77 bcd	40.87 ab	72.73 a	76.01 a
V_2M_1	16.33 l	27.62 ij	43.13 h	45.63 g
V_2M_2	18.85 fgh	34.29 ef	52.67 fg	55.85 ef
V_2M_3	20.71 b-e	36.37 cde	57.50 e	60.92 d
V_2M_4	18.07 g-j	30.96 gh	51.84 fg	54.39 ef
V_2M_5	21.05 bc	37.87 bcd	61.82 d	65.55 c
V_2M_6	21.79 ab	40.44 b	62.65 cd	66.11 bc
V_2M_7	22.53 a	43.32 a	64.11 cd	67.95 bc
$LSD_{(0.05)}$	1.168	2.725	2.039	2.091
CV (%)	3.61	4.65	2.00	1.95

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

At 80 DAS, the treatment V_1M_7 was showed highest plant height (72.73 cm) that was statistically similar to V_1M_6. The second highest (70.63 cm) plant height was recorded in V_1M_5 which was statistically also non-significant with V_1M_6 treatment. The third highest plant height (66.67 cm) that statistically insignificant with V_1M_2, V_2M_6 and V_2M_7. On the other hand, the shortest plant (43.13 cm) was observed in V_2M_1 which was statistically dissimilar to other treatments. The second shortest plant was found from V_1M1 (50.21 cm) that statistically non-significant with V_2M_2 and V_2M_4.

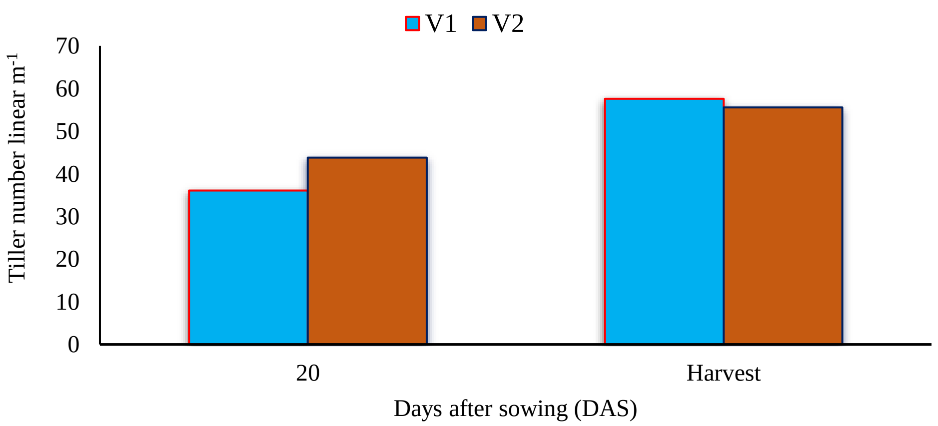
The remaining all other treatments performed numerically more or less same plant height but statistically significant. Plant height was increased by 44.85% due to the interaction of variety and complete agronomic managements compared to control management.

At harvesting stage, the tallest plant was found in V_1M_7 (76.01 cm) followed by V_1M_5 and V_1M_6 these statistically similar. The second tallest plant was recorded in V_1M_3 (71.21 cm) that was statistically insignificant with V_1M_3, V_2M_6 and V_2M_7. The third tallest plant (65.55 cm) was observed in V_2M_5 that which also statistically non-significant with previously mentioned three treatments. On the other hand, the shortest plant was also found in V_2M_1 (45.63 cm) that statistically significant from others. The second shortest plant (52.28 cm) was observed in V_1M_1 that statistically similar to V_2M_4 and V_2M_2. The remaining all other treatments performed numerically more or less same plant height but statistically significant. From the discussion, the results were concluded that plant height varied significantly due to the influence of variety and agronomic managements, specially irrigation considered a most limiting factor for plant height of wheat. Islam *et al*. (2018) also found that growth and yield parameters showed lower performances under no moisture (irrigation) treatments. Similar results were also supported by the findings of Mahmud (2017) and Das (2016).

4.1.3 Number of tillers linear m^{-1}

4.1.3.1 Effects of variety

Statistically significant varietal variation on tiller number was found at 20 DAS but non-significant effect was found at harvest stage (Appendix VI & Fig. 5). At 20 DAS, higher tiller number (43.81) was reported in BARI Gom-32 compared to BARI Gom-30 (34.29) that was supported the previously mentioned information of plant population per unit area. At harvesting, BARI Gom-30 was showed higher tiller number (57.62) compared to that of BARI Gom-32 (55.95). BARI Gom-30 showed 40.37% higher tillering capacity compared to BARI Gom-32. The result was supported by the findings of Azad *et al.* (2017) and Kamrozzaman *et al.* (2016).

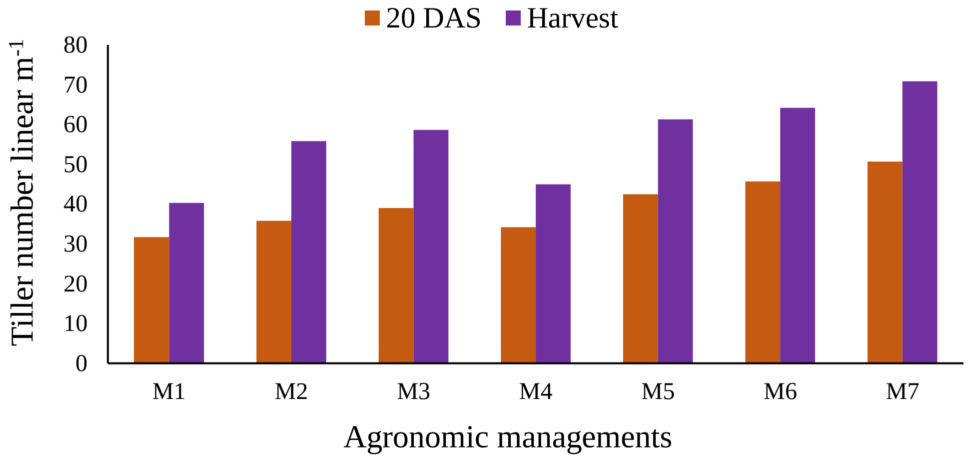


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 5. Effects of variety on tiller number at different growth stages of wheat (LSD$_{(0.05)}$= 5.327 at 20 DAS).

4.1.3.2 Effects of agronomic managements

A statistically significant effect of agronomic managements was observed on tiller number at different growth stages of wheat (Appendix VI & Fig. 6). At 20 DAS, the highest tiller number (50.67) was recorded in M_7 (complete management) which was statistically insignificant with others. The second and third highest tiller number (45.67), (42.50) was counted in M_6 (no pesticides) and M_5 (no thinning) and they were statistically dissimilar to others. On the contrary, the lowest tiller number (31.67) was reported in M_1 (control) that was statistically significant (34.17) with M_4 (No irrigation). The second lowest tiller number (35.83) was found in M_2 (no fertilizer) that was statistically similar to M_4 and the third lowest tiller number (39.00) was counted in M_3 (no weeding). M_7 (complete management) treatment showed 59.99% higher tiller number due to its suitable growing condition compared to M_1 (no management).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 6. Effects of agronomic managements on tiller number at different growth stages of wheat ($LSD_{(0.05)}$= 2.660 and 1.979 at 20 DAS and harvest, respectively).

At harvest, the highest tiller number (70.83) was also recorded in M_7 (complete managements) that was statistically dissimilar to others. The second highest (64.17) tiller number was observed in M_6 that was significant from others. The M_6 (No pest management) was showed 10.38% lower tiller number compared to M_7 (complete management). The third highest (61.33) tiller number was observed in M_5 (No thinning) which was statistically different from others. The M_5 was reduced tiller number by 15.49% compared to M_7 due to competition among them. Similar result also found by Rickman *et al.* (1983). On the other hand, the lowest (40.33) tiller number was counted in M_1 (control) which was statistically insignificant with others. Tiller number was drastically reduced in M_1 due to no agronomic managements. The second lowest tiller number (45.00) was recorded in M_4 (No irrigation) that was statistically significant with others.

The M_4 treatment showed 57.40% lower tillering capacity compared to M_7 (complete management) due to no irrigation applying. Number of fertile tiller unit^{-1} area was significantly increased by increasing the number of irrigation and nitrogen levels that reported by Asif *et al*. (2012). The third lowest (55.83) tiller number was counted in M_2 (No fertilizer) that was significant with others. Ahmad and Irshad (2011) also found that boron application with NPK at sowing time to wheat increased significantly the number of tillers plant^{-1} (15%).

4.1.3.3 Interaction effects of variety and agronomic managements

Statistically significant variation was found on tiller number due to the influence of variety and agronomic managements at different growth stages of wheat (Appendix VI & Table 3).

Table 3. Influence of variety and agronomic managements on tiller number of wheat at different growth stages

Treatment combinations	Tiller number linear m^{-1} at	
	20 DAS	Harvest
V_1M_1	30.00 j	38.67 j
V_1M_2	31.00 ij	57.67 f
V_1M_3	34.00 hi	59.33 ef
V_1M_4	32.67 hij	42.00 i
V_1M_5	38.00 fg	64.00 cd
V_1M_6	40.67 ef	67.00 b
V_1M_7	46.00 cd	74.67 a
V_2M_1	33.33 hij	42.00 i
V_2M_2	40.67 ef	54.00 g
V_2M_3	44.00 cde	58.00 f
V_2M_4	35.67 gh	48.00 h
V_2M_5	47.00 bc	58.67 ef
V_2M_6	50.67 b	61.33 de
V_2M_7	55.33 a	67.00 b
$LSD_{(0.05)}$	3.762	2.799
CV (%)	5.59	2.93

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

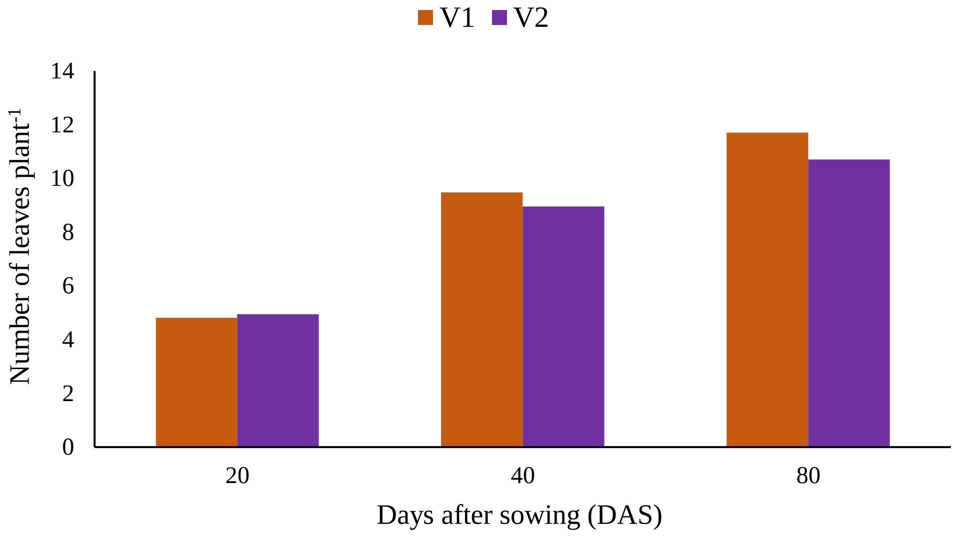
At 20 DAS, the maximum tiller number (55.33) was found in V_2M_7 (BARI Gom-32 with complete management) that statistically dissimilar to others. The second maximum tiller number (50.67) was counted in V_2M_6 (BARI Gom-32 with no pest management) that statistically insignificant with V_2M_5. The V_2M_6 treatment showed 9.20% lower tiller number compared to V_2M_7 due to no pest management. Based on the total number of spikes, the number of healthy spikes and the number of scabbed spikes were lost around 12% due to no pest management (Casa *et al.*, 2004). The third maximum tiller number (46.00) was recorded in V_1M_7 (BARI Gom-30 with complete management) that was also similar to V_2M_3 (44.00). The minimum tiller number (30.00), (31.00), (32.67) and (33.33) were recorded from V_1M_1, V_1M_2, V_1M_4 and V_2M_1 and they were statistically similar. The second minimum tiller number (34.00) was found in V_1M_3 which was statistically similar to V_1M_2, V_1M_4 and V_2M_1. The third minimum tiller number (35.67) was observed in V_2M_4 that was also statistically insignificant with V_1M_3, V_1M_4 and V_2M_1.

At harvest, the highest tiller number was recorded in V_1M_7 (74.67) that statistically different from others. The second highest (67.00) tiller number was counted in V_2M_7 that statistically similar to V_1M_6 (67.00). The third highest tiller number was noted in V_1M_5 (64.00) which was statistically non-significant with others. The lowest tiller number (38.67) was counted in V_1M_1 which was statistically dissimilar to others. The second lowest tiller number was observed in V_2M_1 (42.00) and V_1M_4 (42.00) and they were statistically similar. The third minimum tiller number was counted in V_2M_4 (48.00) that was distinct from others. From the above discussion, it was clear that BARI Gom-32 with complete agronomic managements showed higher tiller number compared to BARI Gom-30 with recommended managements at 20 DAS. But at harvest, BARI Gom-30 with recommended managements showed maximum tillers number compared to BARI Gom-32 due to higher tillering capacity of BARI Gom-30 with agronomic managements. Azad *et al*. (2017) reported that tillering capacity of BARI Gom-30 was higher compared to BARI Gom-32.

4.1.4 Number of leaves plant^{-1}

4.1.4.1 Effects of variety

Statistically significant effect of variety on leaves number was noticed at 80 DAS, but non-significant effect was observed at 20 DAS and 40 DAS (Appendix VII & Fig. 7). At 20 DAS, BARI Gom-30 showed (4.81) and BARI Gom-32 (4.95) showed similar number of leaves plant^{-1}. Similar non-significant variation of leaves number plant^{-1} also observed at 40 DAS between the two varieties. At 80 DAS, higher leaves number (11.71) was recorded in BARI Gom-30 which was statistically significant with BARI Gom-32 (10.71). From the above discussion, it was clear that BARI Gom-30 showed higher leaves compared to BARI Gom-32 might be due to its genetical characters. Azad *et at.* (2017) gave their opinion that BARI Gom-30 showed higher leaves number compared to the BARI Gom-32. Kamrozzaman *et al.* (2016) also opined that number of leaves plant^{-1} of wheat varied with variety to variety.



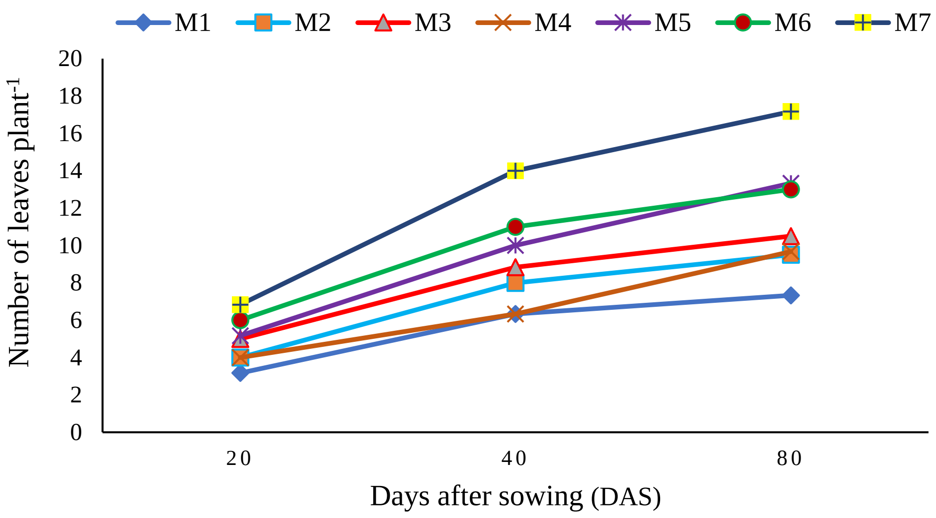
V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 7. Effects of variety on leaves number of wheat at different growth stages ($LSD_{(0.05)}$= 0.939 at 80 DAS).

4.1.4.2 Effects of agronomic managements

Different agronomic managements showed statistically significant variation on leaves number at 20, 40 and 80 DAS (Appendix VII & Fig. 8). At 20 DAS, maximum leaves were recorded in M_7 (6.83) which was statistically different from others and second maximum was recorded in M_6 (6.00) that was also dissimilar to others. Third maximum leaves number were counted in M_5 (5.17) and M_3 (5.00) and they were statistically similar. On the other hand, the minimum leaves number (3.17) were counted in M_1 (no management) that was statistically different. The second minimum leaves number were counted in M_2 (4.00) and M_4 (4.00) and they were statistically similar. The M_7 showed maximum leaf number compared to M_1 (control) due to complete agronomic managements. Different agronomic managements showed significant variation on number of leaves $plant^{-1}$ was also found by Mahmud (2017).

At 40 DAS, the highest leaves number $plant^{-1}$ (14.00) was enumerated in M_7 (complete management) that was statistically dissimilar to others. The second and third highest leaves number recorded in M_6 (11.00) and M_5 (10.00), respectively and they were statistically significant with each other. While the lowest leaves number (6.33) was counted in M_1 and M_4 and they were statistically identical. The second and third lowest leaf number was reported in M_2 (8.00) and M_3 (8.33), respectively and they were statistically dissimilar.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 8. Effects of agronomic managements on leaves number of wheat at different growth stages ($LSD_{(0.05)}$= 0.327, 0.805 and 2.167 at 20, 40 and 80 DAS, respectively).

At harvest, the maximum leaf number (15.17) was reported in M_7 (complete management) which was statistically non-significant with M_5 (no thinning). The second maximum leaf number (13.00) was recorded in M_6 (no pesticides) that was also statistically similar to M_5. The M_5 and M_6 showed 13.80% and 16.69% lower leaves number compared to M_7 (complete management). On the contrary, the minimum leaves number (7.33) was also counted in M_1 (no management) that was statistically different to others. The second minimum leaves number (9.50) was reported in M_2 (no fertilizer) which was statistically similar to M_4 (9.67) and M_3 (10.50).

4.1.4.3 Interaction of variety and agronomic managements

Statistically significant variation was found on leaves number due to the influence of variety and agronomic managements at different growth stages of wheat (Appendix VII & Table 4). At 20 DAS, the maximum leaves number was enumerated in V_2M_7 (7.00) and V_1M_7 (6.67) and they were statistically insignificant with themselves and dissimilar to others. The second maximum leaves number (6.00) was counted in V_1M_6 and V_2M_6 and they were statistically similar. Leaves number was decreased by 16.67% in V_1M_6 and V_2M_6 compared to V_2M_7 due to no pest management. The third maximum leaves number (5.33) was recorded in V_2M_5 which was statistically similar to V_1M_3 (5.00), V_1M_5 (5.00) and V_2M_3 (5.00). On the other hand, the minimum leaves number was reported in V_1M_1 (3.00) and V_2M_1 (3.33) and they were statistically non-significant. The second minimum leaves number (4.00) was counted in V_1M_2, V_1M_4, V_2M_2 and V_2M_4 and they were statistically similar.

Table 4. Interaction of variety and agronomic managements on leaf number of wheat at different growth stages

Treatment combinations	Leaf number plant^{-1} at		
	20 DAS	40 DAS	80 DAS
V_1M_1	3.00 e	6.67 gh	7.33 g
V_1M_2	4.00 d	8.67 def	10.00 efg
V_1M_3	5.00 c	9.33 cde	11.00 c-f
V_1M_4	4.00 d	6.67 gh	10.67 def
V_1M_5	5.00 c	10.00 bc	13.33 a-d
V_1M_6	6.00 b	11.00 b	14.00 abc
V_1M_7	6.67 a	14.00 a	15.67 a
V_2M_1	3.33 e	6.00 h	7.33 g
V_2M_2	4.00 d	7.33 fg	9.00 efg
V_2M_3	5.00 c	8.33 ef	10.00 efg
V_2M_4	4.00 d	6.00 h	8.67 fg
V_2M_5	5.33 c	10.00 bcd	13.33 a-d
V_2M_6	6.00 b	11.00 b	12.00 b-e
V_2M_7	7.00 a	14.00 a	14.67 ab
$LSD_{(0.05)}$	0.463	1.138	3.064
CV (%)	5.63	7.33	16.21

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

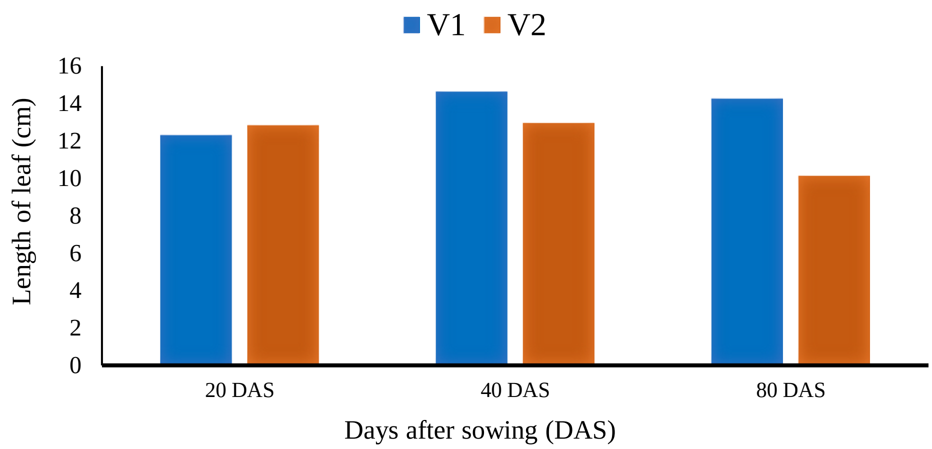
At 40 DAS, the highest leaves number (14.00) was counted in V_1M_7 and V_2M_7 and they were statistically insignificant themselves and different from others. The second highest leaves number was counted in V_1M_6 (11.00) and V_2M_6 (11.00) and they were statistically similar to V_1M_5 (10.00) and V_2M_5 (10.00). The third highest (9.33) leaves number was recorded in V_1M_3 which was also statistically non-significant with V_1M_5 and V_2M_5. The lowest number of leaves (6.00) was recorded in V_2M_1 and V_2M_4 and they were statistically insignificant with V_1M_1 (6.67) and V_1M_4 (6.67). The second lowest leaves number (7.33) was reported in V_2M_2 which was also statistically similar to V_1M_1 (6.67) and V_1M_4 (6.67). The third lowest leaves number (8.33) was enumerated in V_2M_3 which was statistically insignificant with V_1M_2 and V_2M_2.

At 80 DAS, the maximum leaves number was recorded in V_1M_7 (15.67) that was statistically similar to V_2M_7 (14.67), V_1M_6 (14.00), V_1M_5 (13.33) and V_2M_5 (13.33). The second maximum leaves number (12.00) was counted in V_2M_6 which was also statistically similar to previously mentioned fours. The third maximum leaves number (11.00) was reported in V_1M_3 which was statistically similar to V_2M_6 and also to V_1M_6, V_1M_5 and V_2M_5. The minimum leaves number (7.33) was enumerated in V_1M_1 and V_2M_1 and they were statistically insignificant with V_2M_4, V_2M_2, V_2M_3 and V_1M_2. The second minimum leaves number was recorded in V_2M_4 (8.67) which was statistically similar to V_1M_4, V_2M_2, V_2M_3, V_1M_2 and V_1M_3. The third minimum leaves number was counted in V_1M_4 (10.67) that was also statistically insignificant with V_2M_2, V_2M_3, V_1M_2, V_1M_5, V_2M_5, V_2M_6 and V_1M_3. At 20 DAS, BARI Gom-32 with complete agronomic management showed higher leaves number but at harvest BARI Gom-30 with complete management showed higher leaves number. This was supported by the findings of Azad *et al*. (2017).

4.1.5 Length of leaf

4.1.5.1 Effects of variety

A statistically significant variation on leaf length was observed due to the variety at 40 and 80 DAS but at 20 DAS leaf number didn’t show any significant variation between the two variety (Appendix VIII & Fig. 9). At 20 DAS, BARI Gom-30 and BARI Gom-32 showed (12.31cm) and (12.83 cm) leaves number, respectively and they were statistically non-significant. At 40 DAS, BARI Gom-30 showed maximum length of leaf (14.63 cm) compared to BARI Gom-32 (12.96 cm) due to fully vegetative growing phase. At 80 DAS, both the variety showed lower leaf length and gave attention on reproductive phase. BARI Gom-30 reduced leaf length (14.25 cm) lower compared to BARI Gom-32 (10.13 cm). From the discussion, it was clear that BARI Gom-30 showed higher length of leaf compared to BARI Gom-32 might be due to its genetical characters. Azad *et al*. (2017) conducted a field study at BARI research field to assess growth and yield of wheat and they opined that BARI Gom-30 showed longer leaves whereas BARI Gom-32 showed shorter leaves.

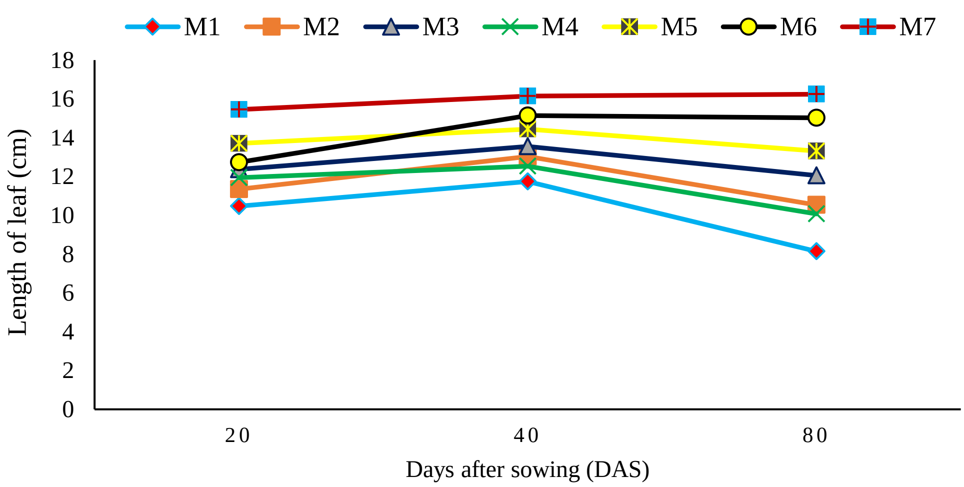


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 9. Effects of variety on length of leaf of wheat at different growth stages ($LSD_{(0.05)}$= 0.776 and 0.401 at 40 and 80 DAS, respectively).

4.1.5.2 Effects of agronomic managements

Different agronomic managements showed significant variations on leaves length at different growth stages of wheat (Appendix VIII & Fig. 10). At 20 DAS, the longest leaf was found in M_7 (15.45 cm) that was statistically significant with other treatments. The second longest leaf (13.70 cm) was observed in M_5 which was statistically different from others. The M_5 treatment decreased leaf length by 12.77% compared to M_7 due to the effects of no thinning. The third longest leaf was recorded in M_6 (12.73 cm) which was statistically insignificant with M_3 (12.36 cm).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 10. Effects of agronomic managements on length of leaf of wheat at different growth stages ($LSD_{(0.05)}$= 0.654, 0.977 and 1.044 at 20, 40 and 80 DAS, respectively).

The M_6 treatment reduced leaf length by 21.37% compared to M_7 due to no pest management. Khan *et al.* (2012) reported that pest cause yield losses either directly (35-40%) by sucking the sap of the plants or indirectly (20-80%) by transmitting viral and fungal diseases. The M_3 treatment declined leaf length by 25% compared to M_7 due to no weeding. Santosh *et al*. (2018) reported that 19 to 25 percent yield loss was observed due to 44-56 percent shading of the crop by the weeds. On the contrary, the shortest leaf was observed in M_1 (10.47 cm) that was statistically dissimilar to others. The second shortest leaf (11.34 cm) was found in M_2 which was statistically non-significant with M_4 (11.94 cm). The M_2 treatment decreased leaf length by 36.24% compared to M_7 due to no fertilizer application. Bazzaz *et al*. (2008) proclaimed that application up to 120 kg N ha^{-1} and 1.0 kg B ha^{-1} significantly increased leaf length of wheat. The M_4 treatment reduced leaf length by 29.40% compared to M_7 due to no irrigation.

At 40 DAS, maximum length of leaf was found in the all treatments compared to 20 and 80 DAS. The longest leaf (16.15 cm) was observed in M_7 that was statistically significant from others. The second longest leaf (15.14 cm) was found in M_6 which was statistically insignificant with M_5 (14.44 cm). The M_6 and M_5 treatments decreased leaf length by 6.67% and 11.84%, respectively compared to M_7 due to no pest control and no thinning. The second longest leaf was recorded in M_3 (13.55 cm) that was statistically similar to M_2 (13.03 cm). On the other hand, the shortest leaf (11.74 cm) was found in M_1 (control) which was statistically non-significant with M_4 (12.53 cm). The M_4 treatment showed shorter leaf due to no irrigation. It means that without irrigation other managements didn't perform well.

At 80 DAS, all the treatment decreased leaf length except M_7. The M_7 showed maximum leaf length (16.24 cm) which was statistically different from others. The second maximum length of leaf (15.02 cm) was found in M_6 that was statistically significant from others. The third maximum length of leaf was recorded in M_5 (13.31 cm) which was also statistically dissimilar to others. While the minimum length of leaf was observed in M_1 (8.14 cm) that was statistically different from others. The second and third minimum leaf length (10.07 cm) and (12.05 cm) were recorded in M_4 and M_3, respectively and M_4 was statistically similar to M_2 (10.53 cm).

4.1.5.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed significant differences on length of leaf at different growth stages of wheat (Appendix VIII & Table 5). At 20 DAS, the maximum leaf of length (16.42 cm) was recorded in V_2M_7 which was statistically significant from others. The second maximum length of leaf was found in V_1M_7 (14.49 cm) that was statistically similar to V_2M_5 (13.91 cm). The third maximum leaf length was recorded in V_2M_3 (13.11 cm) which was statistically insignificant with V_1M_5 (13.49 cm), V_1M_6 (13.02 cm) and V_2M_5 (13.91 cm). On the contrary, the minimum length of leaf (10.34 cm) was observed in V_1M_1 that was statistically similar to V_2M_1 (10.61 cm).

The second minimum length of leaf was recorded in V_1M_2 (11.25 cm) which was statistically non-significant with V_2M_1 and all other treatments showed more or less similar leaf length at this growth stage.

Table 5. Interaction of variety and agronomic managements on leaf length of wheat at different growth stages

Treatment combinations	Length of leaf (cm) at		
	20 DAS	40 DAS	80 DAS
V_1M_1	10.34 m	12.49 def	9.75 gh
V_1M_2	11.25 h-l	14.11 bc	12.40 ef
V_1M_3	11.61 hij	14.26 bc	14.15 d
V_1M_4	11.96 gh	13.66 cd	11.00 fg
V_1M_5	13.49 cd	15.36 ab	15.75 c
V_1M_6	13.02 c-f	16.02 a	17.43 b
V_1M_7	14.49 b	16.54 a	19.30 a
V_2M_1	10.61 klm	10.99 g	6.53 i
V_2M_2	11.44 h-k	11.96 efg	8.67 h
V_2M_3	13.11 cde	12.84 cde	9.95 gh
V_2M_4	11.91 ghi	11.40 fg	9.13 h
V_2M_5	13.91 bc	13.51 cd	10.87 g
V_2M_6	12.44 efg	14.25 bc	12.60 e
V_2M_7	16.42 a	15.76 a	13.17 de
$LSD_{(0.05)}$	0.924	1.381	1.476
CV (%)	4.36	5.94	7.18

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

At 40 DAS, the highest leaf length was found in V_1M_7 (16.54 cm) that was statistically insignificant with V_2M_7 (15.76 cm), V_1M_6 (16.02 cm) and V_1M_5 (15.36 cm). The second highest length of leaf (14.26 cm) was recorded in V_1M_3 which was statistically similar to V_1M_2, V_2M_6 and also to V_1M_5. The third longest leaf was observed in V_1M_4 (13.66 cm) that was statistically non-significant with V_2M_3, V_2M_5 and also with V_1M_2, V_1M_3 and V_2M_6. Whereas the shortest leaf was recorded in V_2M_1 (10.99 cm) that was statistically similar to V_2M_2 and V_2M_4.

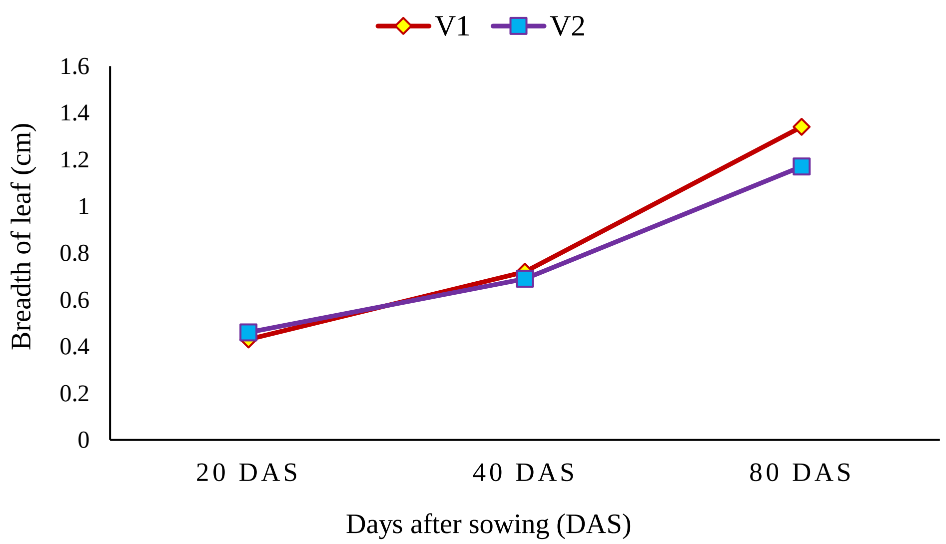
The second shortest leaf (12.49 cm) was found in V_1M_1 which was also statistically insignificant with V_2M_2 and V_2M_4. The third shortest leaf was recorded in V_2M_3 (12.84 cm) that was also statistically similar to V_1M_1 and all other treatments showed more or less similar leaf length at this growth stage.

At 80 DAS, the maximum length of leaf (19.30 cm) was found in V_1M_7 which was statistically dissimilar to others. The second maximum leaf length was recorded in V_1M_6 (17.43 cm) that was statistically different from others. The V_1M_6 treatment reduced leaf length by 10.73% compared to V_1M_7 (complete management). The third maximum leaf length (15.75 cm) was observed in V_1M_5 that was statistically identical to others treatment. On the other hand, the minimum length of leaf (6.53 cm) was found in V_2M_1 which was statistically different from others. The second minimum length of leaf was recorded in V_2M_2 (8.67 cm) that was similar to V_1M_1 (9.75), V_2M_3 (9.95) and V_2M_4. The third minimum leaf length (10.87 cm) was reported in V_2M_5 which was statistically similar to V_1M_4 and also to V_1M_1 (9.75) and V_2M_3 (9.95). This result showed that BARI Gom-30 with complete management gave higher length of leaves compared to BARI Gom-32 with complete management.

4.1.6 Breadth of leaf

4.1.6.1 Effects of variety

Breadth of leaf varied insignificantly at 40 DAS and statistically significant at 20 and 80 DAS of BARI Gom-30 and BARI Gom-32 (Appendix IX & Fig. 11).



V_1= BARI Gom-30 and V_2= BARI Gom-32

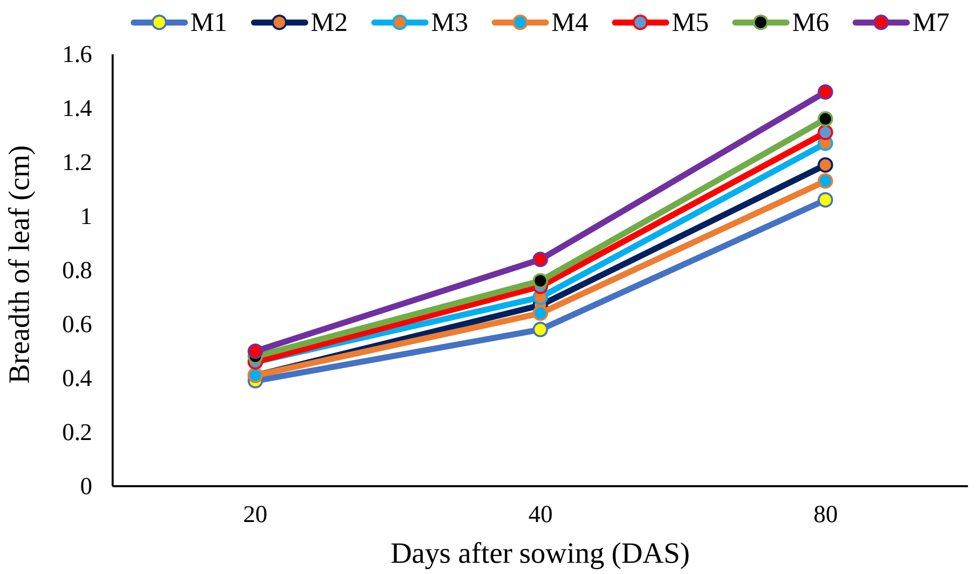
Figure 11. Effects of variety on breadth of leaf of wheat at different growth stages ($LSD_{(0.05)}$= 0.025 and 0.054 at 20 and 80 DAS, respectively).

At 20 DAS, BARI Gom-32 showed higher leaf breadth (0.46 cm) compared to BARI Gom-30 (0.43 cm) and they were statistically significant. At 40 DAS, BARI Gom-30 showed numerically higher (0.72 cm) leaf breadth compared to BARI Gom-32 (0.69 cm) but they were statistically insignificant. At 80 DAS, the higher breadth of leaf was observed in BARI Gom-30 (1.34 cm) which was statistically dissimilar to BARI Gom-32 (1.17 cm). From the above interpretation, it clear that BARI Gom-30 showed higher breadth of leaf compared to BARI Gom-32 might be due to its genetical characters.

4.1.6.2 Effects of agronomic managements

A statistically significant effect of agronomic managements was observed on leaf breadth at different growth stages of wheat (Appendix IX & Fig. 12). At 20 DAS, the highest breadth of leaf was recorded in M_7 (0.50 cm) that was statistically dissimilar to others. On the contrary, the lowest leaf breadth (0.39 cm) was found in M_1 (No management) which was statistically dissimilar to others and all other treatments showed leaf breadth between the two at this growth stage.

At 40 DAS, maximum leaf breadth (0.84 cm) was also recorded in M_7 which was statistically different from others. The second maximum leaf breadth (0.76 cm) was found in M_6 (no pesticides) that was statistically significant with M_5 (0.74 cm). While the minimum leaf breadth (0.58 cm) was reported in M_1 (no management) which was statistically different from other treatments and remaining three treatments showed leaf breadth between them.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 12. Effects of agronomic managements on breadth of leaf of wheat at different growth stages ($LSD_{(0.05)}$= 0.013, 0.037 and 0.086 at 20, 40 and 80 DAS, respectively).

At 80 DAS, the highest leaf breadth was observed in M_7 (1.46 cm) which was statistically significant with others. The second highest leaf breadth (1.36 cm) was recorded in M_6 that was statistically non-significant with M_5 (1.31 cm). Whereas the lowest leaf breadth (1.06 cm) was found in M_1 which was statistically similar to M_4 (1.13 cm) and remaining two treatments showed statistically similar breadth of leaf. From the above discussion, it may conclude that both the variety with complete management gave higher breadth of leaf compared to no agronomic managements.

4.1.6.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed significant differences on breadth of leaf at different growth stages of wheat (Appendix IX & Table 6).

Table 6. Interaction of variety and agronomic managements on leaf breadth of wheat at different growth stages

Treatment combinations	Breadth of leaf (cm) at		
	20 DAS	40 DAS	80 DAS
V_1M_1	0.39 h	0.60 ij	1.07 h
V_1M_2	0.40 g	0.67 fgh	1.29 de
V_1M_3	0.42 fg	0.71 def	1.33 cd
V_1M_4	0.41 fgh	0.62 hi	1.16 fgh
V_1M_5	0.43 ef	0.75 cd	1.41 bc
V_1M_6	0.45 e	0.79 bc	1.47 b
V_1M_7	0.48 cd	0.87 a	1.63 a
V_2M_1	0.39 h	0.55 j	1.05 h
V_2M_2	0.43 ef	0.67 fgh	1.09 gh
V_2M_3	0.49 bc	0.69 efg	1.20 efg
V_2M_4	0.42 fg	0.65 ghi	1.11 gh
V_2M_5	0.48 cd	0.73 de	1.20 efg
V_2M_6	0.51 ab	0.73 de	1.24 def
V_2M_7	0.52 a	0.81 b	1.29 cde
$LSD_{(0.05)}$	0.018	0.053	0.122
CV (%)	2.46	4.41	5.78

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

At 20 DAS, the highest breadth of leaf was recorded in V_2M_7 (0.52 cm) which was statistically insignificant with V_2M_6 (0.51 cm). The second highest (0.49 cm) breadth of leaf was found in V_2M_3 that was also statistically similar to V_2M_6. The third highest breadth of leaf was observed in V_1M_7 (0.48 cm) which was statistically non-significant with V_2M_5 and V_2M_3. While the lowest breadth of leaf (0.39 cm) was recorded in V_1M_1, V_2M_1 and they were statistically similar to V_1M_4 (0.41 cm). The V_1M_1 and V_2M_1 decreased breadth of leaves by 33.33% compared to V_2M_7 due to no management and V_1M_4 reduced by 26.83% due to no irrigation. The remaining all other treatments showed more or less same breadth of leaf.

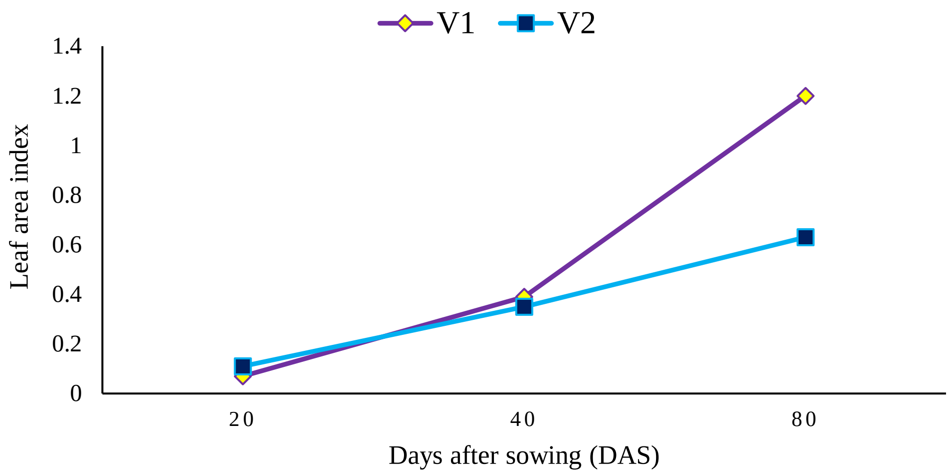
At 40 DAS, the maximum breadth of leaf (0.87 cm) was recorded in V_1M_7 that was statistically different from others. The second maximum leaf breadth was observed in V_2M_7 (0.81 cm) which was statistically insignificant with V_1M_6 (0.79 cm). The V_1M_6 treatment showed 10.13% lower breadth of leaf compared to V_1M_7 due to no pest management. The third maximum leaf breadth was reported in V_1M_5 (0.75 cm) that was statistically non-significant with V_1M_6. On the contrary, the minimum breadth of leaf was found in V_2M_1 (0.55 cm) which was statistically similar to V_1M_1 (0.60 cm). The second minimum breadth of leaf (0.62 cm) was recorded in V_1M_4 that was statistically similar to V_2M_4 (0.65 cm). The V_1M_4 and V_2M_4 treatments decreased leaf breadth by 40.32% and 33.85% respectively compared to V_1M_7 due to no irrigation. All other treatments showed more or less same breadth of leaf at this growth stage.

At 80 DAS, the maximum breadth of leaf (1.63 cm) was recorded in V_1M_7 that was statistically different from others. The second maximum leaf breadth was observed in V_1M_6 (1.47 cm) which was statistically insignificant with V_1M_5 (1.41 cm). The V_1M_6 treatment showed 10.88% lower breadth of leaf compared to V_1M_7 due to no pest management. The third maximum leaf breadth was reported in V_1M_3 (1.33 cm) that was statistically non-significant with V_1M_5 and V_2M_7. On the contrary, the minimum breadth of leaf was found in V_2M_1 (1.05 cm) which was statistically similar to V_1M_1 (1.07 cm), V_1M_4, V_2M_2 and V_2M_4. The second minimum breadth of leaf (1.20 cm) was recorded in V_2M_3 and V_2M_5 that was statistically similar to V_2M_2 (1.09 cm) and V_1M_4. The V_2M_3 and V_2M_5 treatments decreased leaf breadth by 35.83% compared to V_1M_7 due to no weeding and thinning, respectively. All other treatments showed more or less same breadth of leaf at this growth stage.

4.1.7 Leaf Area Index (LAI)

4.1.7.1 Effects of variety

A statistically significant variation was noticed by the influence of variety on leaf area index of wheat at 20, 40 and 80 DAS (Appendix X & Fig. 13). At 20 DAS, BARI Gom-32 showed higher (0.11) leaf area index compared to BARI Gom-30 (0.07). BARI Gom-32 increased leaf area index by 57.14% compared to BARI Gom-30. But 40 and 80 DAS, BARI Gom-30 showed higher leaf area index 0.39 and 1.20 compared to BARI Gom-32 (0.35 and 0.63), respectively. BARI Gom-30 increased leaf area index by 11.43% and 90.48% compared to BARI Gom-32 at 40 and 80 DAS, respectively. Din *et al.* (2018) showed leaf area index varied in variety to variety.

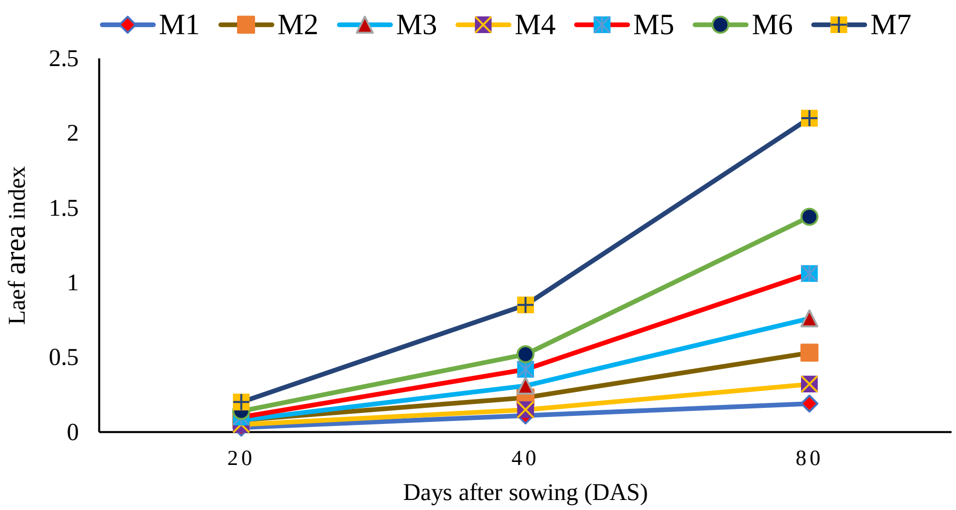


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 13. Effects of variety on leaf area index of wheat at different growth stages ($LSD_{(0.05)}$= 0.021, 0.036 and 0.159 at 20, 40 and 80 DAS, respectively).

4.1.7.2 Effects of agronomic managements

Statistically significant variation was observed on leaf area index of wheat by the influence of different types of agronomic management at 20, 40 and 80 DAS (Appendix X & Fig. 14). At 20 DAS, the maximum leaf area index was recorded in M_7 (0.20) that was statistically dissimilar to others. On the contrary, the minimum leaf area index 0.03 was found in M_1 (no management) which was statistically dissimilar to others and all other treatments showed leaf area index between the two at this growth stage.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 14. Effects of agronomic managements on leaf area index of wheat at different growth stages ($LSD_{(0.05)}$= 0.011, 0.049 and 0.187 at 20, 40 and 80 DAS, respectively).

At 40 DAS, maximum leaf area index (0.85) was also recorded in M_7 which was statistically different from others. The second maximum leaf area index (0.52) was found in M_6 (no pesticides) that was statistically dissimilar to other treatment. The M_6 treatment decreased leaf area index by 63.46% compared to M_7 (complete management). The third maximum leaf index (0.42) was recorded in M_5 (no thinning) that was statistically significant with others and it decreased leaf area index by 23.81% compared to M_7. While the minimum leaf area index (0.11) was reported in M_1 (no management) which was statistically similar to M_4 treatment and remaining two treatments showed leaf area index between them.

At 80 DAS, the highest leaf area index was observed in M_7 (2.10) which was statistically significant with others. The second highest leaf area index (1.44) was recorded in M_6 that was statistically significant with others and it decreased leaf area index by 45.83% compared to M_7. Whereas the lowest leaf area index (0.19) was found in M_1 which was statistically similar to M_4 (0.32). The second lowest leaf area index (0.53) was recorded in M_2 (no fertilizer) that was statistically dissimilar to others and it decreased leaf area index compared to M_7. Similar results were also found by Nadim *et al.* (2013), Asif *et al*. (2012) and Bazzaz *et al*. (2008).

4.1.7.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed significant differences on leaf area index at different growth stages of wheat (Appendix X & Table 7). At 20 DAS, the highest leaf area index was recorded in V_2M_7 (0.24) which was statistically significant with others. The second highest (0.16) leaf area index was found in V_2M_6 that was also statistically similar to V_1M_7 (0.15). The third highest leaf area index was observed in V_2M_5 (0.12) which was statistically non-significant with V_1M_6. While the lowest leaf area index (0.03) was recorded in V_1M_1 and V_2M_1. The remaining all other treatments showed more or less similar leaf area index.

At 40 DAS, the maximum leaf area index (0.89) was recorded in V_1M_7 that was statistically different from others. The second maximum leaf area index was observed in V_2M_7 (0.81) which was statistically significant with others. The third maximum leaf area index was reported in V_1M_6 (0.56) that was statistically non-significant with V_2M_6 (0.49). On the contrary, the minimum leaf area index was found in V_2M_1 (0.10) which was statistically similar to V_1M_1 (0.12), V_1M_4 (0.15) and V_2M_4 (0.14). The second minimum leaf area index (0.20) was recorded in V_2M_2 that was statistically similar to V_1M_2 (0.26). All other treatments showed more or less similar leaf area index at this growth stage.

At 80 DAS, the maximum leaf area index (2.88) was recorded in V_1M_7 that was statistically different from others. The second maximum leaf area index was observed in V_1M_6 (1.88) which was statistically significant with others. The V_1M_6 treatment showed 53.19% lower leaf area index compared to V_1M_7 due to no pest management. The third maximum leaf area index was reported in V_1M_5 (1.40) that was statistically non-significant with V_2M_7. On the contrary, the minimum leaf area index was found in V_2M_1 (0.16) which was statistically similar to V_1M_1, V_1M_4, V_2M_2 and V_2M_4.

The second minimum leaf area index (0.52) was recorded in V_2M_3 that was statistically similar to V_1M_2 (0.69) and V_2M_5 (0.72). All other treatments showed more or less same breadth of leaf at this growth stage.

Table 7. Interaction of variety and agronomic managements on leaf area index of wheat at different growth stages

Treatment combinations	Leaf area index (LAI) at		
	20 DAS	40 DAS	80 DAS
V_1M_1	0.03 h	0.12 k	0.22 g
V_1M_2	0.05 fg	0.26 hi	0.69 e
V_1M_3	0.62 e	0.33 fg	1.00 d
V_1M_4	0.04 fg	0.15 jk	0.33 fg
V_1M_5	0.07 e	0.44 de	1.40 c
V_1M_6	0.11 cd	0.56 c	1.89 b
V_1M_7	0.15 b	0.89 a	2.88 a
V_2M_1	0.03 gh	0.10 k	0.16 g
V_2M_2	0.06 ef	0.20 ij	0.36 fg
V_2M_3	0.10 d	0.29 gh	0.52 ef
V_2M_4	0.05 ef	0.14 jk	0.30 fg
V_2M_5	0.12 c	0.40 ef	0.72 de
V_2M_6	0.16 b	0.49 cd	0.99 d
V_2M_7	0.24 a	0.81 b	1.33 c
$LSD_{(0.05)}$	0.016	0.070	0.265
CV (%)	10.08	11.18	17.20

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

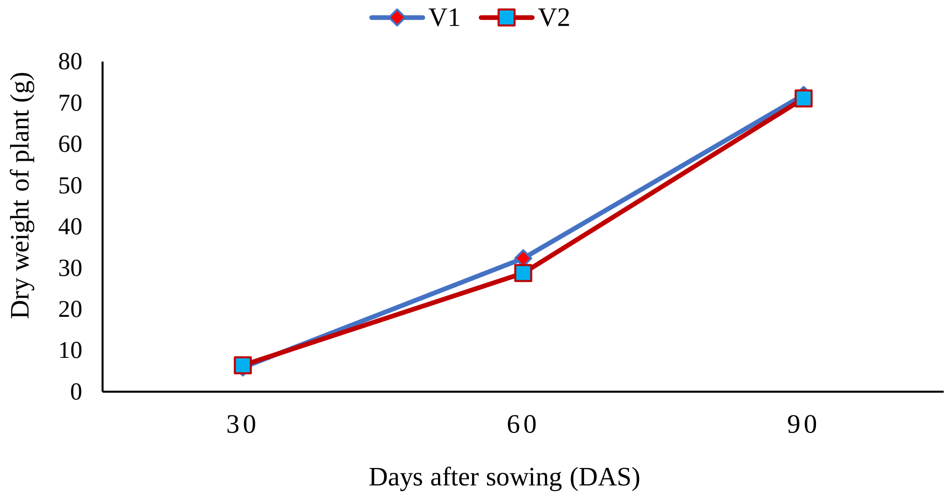
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.1.8 Dry weight of plant linear m^{-1}

4.1.8.1 Effects of variety

The total dry matter weight of plant was significantly influenced by varieties at 30 and 60 DAS but insignificant at 90 DAS (Appendix XI & Fig. 15). At 30 DAS, BARI Gom-32 showed higher dry weight (6.39 g) compared to BARI Gom-30 (5.86 g) and they were statistically significant. At 60 DAS, BARI Gom-30 showed higher dry matter weight (32.29 g) compared to BARI Gom-32 and they were statistically dissimilar.

BARI Gom-30 showed 12.39% higher dry matter production compared to BARI Gom-32 at this growth stage. At 90 DAS, BARI Gom-30 also produced higher (71.91 g) dry matter compared to BARI Gom-32 (71.05 g) but they were statistically non-significant. From the above interpretation, it was clear that BARI Gom-32 produced higher dry matter compared to BARI Gom-30 at initial but at later stage BARI Gom-30 produced higher dry matter compared to BARI Gom-32 might be its genetical characters. Similar results were also found by Azad *et al.* (2017), Mahmud (2017) and Kamrozzaman *et al.* (2016). They opined that dry matter production capacity was varied with variety to variety.



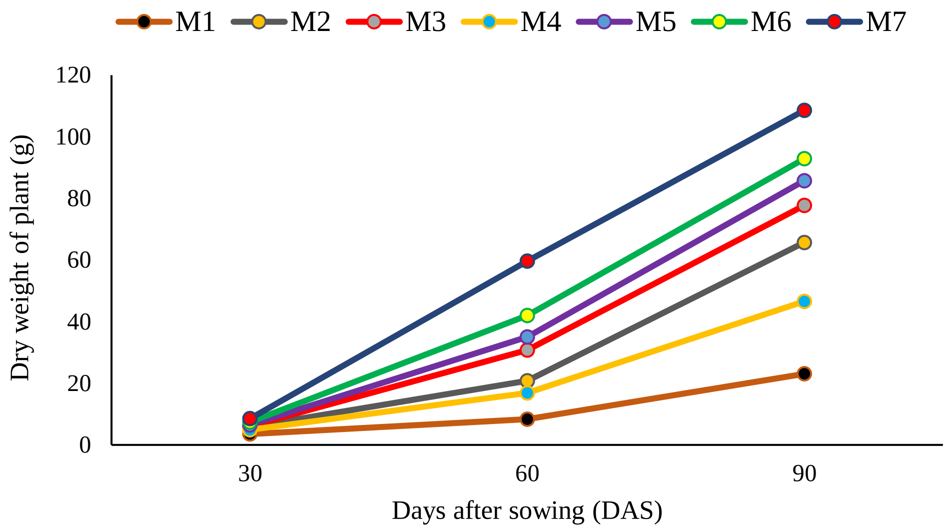
V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 15. Effects of variety on dry weight of plant at different growth stages of wheat (LSD$_{(0.05)}$= 0.506 and 3.556 at 30 and 60 DAS, respectively).

4.1.8.2 Effects of agronomic managements

The total dry matter weight of plant was significantly influenced by different agronomic management practices at different growth stages (Appendix XI & Fig. 16). At 30 DAS, the maximum dry matter weight (8.53 g) was measured in M_7 which was statistically significant from others. The second maximum dry matter weight was found in M_6 (7.83 g) that was statistically dissimilar to others. The third maximum dry weight (6.53 g) was recorded in M_5 which was also statistically different from others. Both the treatments M_5 and M_6 showed lower dry matter production compared to M_7. Zheng *et al.* (2017) showed that decreasing plant density enhanced culm quality, as revealed by increased culm diameter, wall thickness and dry weight per unit length. On the other hand, the minimum dry weight (3.53 g) was weighed in M_1 that was significantly different from others. The second minimum dry weight (4.94 g) was found in M_4 that was statistically different from others. The M_4 treatment showed 72.67% lower dry matter production compared to M_7 due to no irrigation. Atikullah (2014) showed that maximum dry matter content (18.8 g plant^{-1}) by 2 irrigations.

The third minimum dry weight was measured in M_2 (5.83 g) and M_3 (6.10 g) and they were statistically insignificant.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 16. Effects of agronomic managements on dry weight at different growth stages of wheat ($LSD_{(0.05)}$= 0.353, 5.261 and 7.286 at 30, 60 and 90 DAS, respectively).

At 60 DAS, the highest dry weight (59.66 g) was recorded in M_7 which was statistically significant from others. The second highest dry weight was measured in M_6 (41.96 g) that was statistically dissimilar from others. The third highest (35.08 g) dry weight was weighted in M_5 that was statistically similar to M_3 (30.79 g). Whereas the lowest dry weight (8.36 g) was recorded in M_1 which was statistically significant. The second lowest dry weight (16.89 g) was measured in M_4 that was statistically non-significant with M_2 (20.82 g).

At 90 DAS, the highest dry matter production was also observed in M_7 (108.59 g) that was statistically significant from others. The second highest dry weight (92.88 g) was weighted in M_6 that was statistically insignificant with M_5 (85.79 g). The M_6 and M_5 treatments decreased dry matter production by 16.91% and 25.58%, respectively compared to M_7 due to no pest management and thinning. While the lowest dry matter production was observed in M_1 (23.06 g) which was statistically significant from others. The second lowest dry weight (46.60 g) was recorded in M_4 that was statistically dissimilar to others due to no irrigation. The third and fourth lowest dry matter weight was measured in M_2 (65.72 g) and M_3 (77.73 g), respectively and they were statistically dissimilar. The M_2 and M_3 produced 65.23% and 39.70% lower dry matter compared to M_7 due to no fertilizer and weeding, respectively.

This result was also supported by the findings of Hira (2009) who reported that dry weight of plant was increased significantly when irrigation was applied 3 times at CRI, maximum tillering, grain filling stage along with the recommended nitrogen dose of 115 kg ha^{-1}.

4.1.8.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic management packages significantly influenced by the total dry matter weight of plant at different growth stages (Appendix XI & Table 8). At 30 DAS, the maximum dry weight was measured in V_2M_7 (8.55 g) which was statistically insignificant with V_1M_7 (8.50 g).

Table 8. Interaction of variety and agronomic managements on dry weight of wheat at different growth stages

Treatment combinations	Dry weight of plant (g) at		
	30 DAS	60 DAS	90 DAS
V_1M_1	3.56 j	6.10 k	18.74 g
V_1M_2	5.44 gh	17.73 hij	64.75 e
V_1M_3	5.55 gh	32.65 def	82.25 cd
V_1M_4	5.20 hi	15.28 ij	43.12 f
V_1M_5	5.86 fg	37.83 cde	90.43 bc
V_1M_6	6.88 cd	44.08 bc	92.76 b
V_1M_7	8.50 ab	72.38 a	111.32 a
V_2M_1	5.44 gh	10.62 jk	27.38 g
V_2M_2	6.23 ef	23.91 gh	66.69 e
V_2M_3	6.64 de	28.93 fg	73.20 de
V_2M_4	4.68 i	18.50 hi	50.08 f
V_2M_5	7.17 c	32.35 ef	81.15 cd
V_2M_6	7.99 b	39.85 bcd	92.99 b
V_2M_7	8.55 a	46.95 b	105.87 a
$LSD_{(0.05)}$	0.500	7.440	10.303
CV (%)	4.84	14.47	8.55

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

The second maximum dry matter production was recorded in V_2M_6 (7.99 g) that was also statistically similar to V_1M_7. The third maximum dry weight (7.17 g) was weighed in V_2M_5 which was statistically non-significant with V_1M_6 (6.88 g). On the contrary, the minimum dry matter weight was recorded in V_2M_1 (3.50 g) and V_1M_1 (3.56 g) and they were statistically insignificant. The second minimum dry weight (4.68 g) was measured in V_2M_4 which was statistically similar to V_1M_4 (5.20 g). These two treatments showed 82.69% and 64.42% lower dry matter production compared to V_2M_7 due to no irrigation. The remaining treatments showed more or less similar dry matter weight but statistically significant.

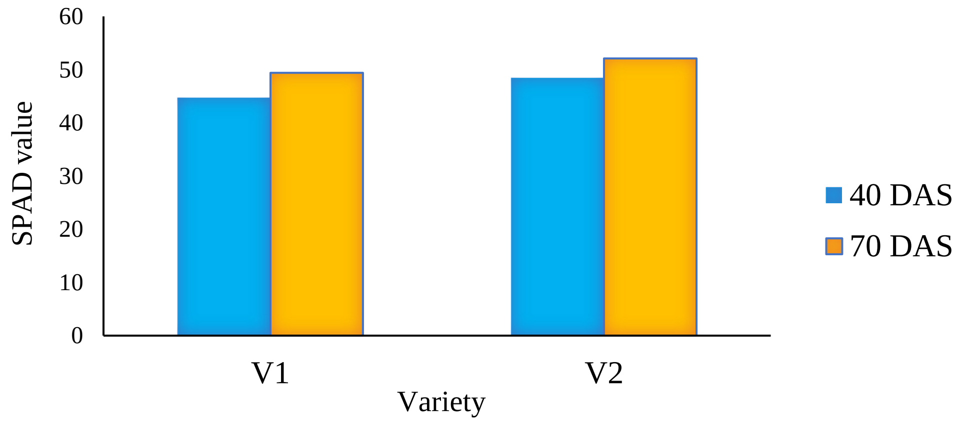
At 60 DAS, the highest dry weight was measured in V_1M_7 (72.38 g) that statistically significant from others. The second highest dry matter weight (46.95 g) was recorded in V_2M_7 which was statistically insignificant with V_1M_6 (44.08 g) and V_2M_6 (39.85 g). The third highest (37.81 g) dry matter weight was observed in V_1M_5 that was statistically similar to V_1M_6 and V_2M_6. While the lowest dry matter production was reported in V_1M_1 (6.10 g) which was statistically non-significant with V_2M_1 (10.62 g). The second lowest dry weight (15.28 g) was recorded in V_1M_4 that was statistically similar to V_1M_2 and V_2M_1. The third lowest dry matter weight (18.50 g) was weighed in V_2M_4 which was also statistically insignificant with V_1M_2 and V_1M_4. The remaining all other treatments showed more or less same dry matter weight but statistically dissimilar.

At 90 DAS, the maximum dry matter production (111.32 g) was weighed in V_1M_7 which statistically non-significant with V_2M_7 (105.87 g). The second maximum dry weight was measured in V_2M_6 (92.99 g) that was statistically similar to V_1M_6 and V_1M_5. The third maximum dry weight was recorded in V_1M_3 (82.25 g) which was statistically insignificant with V_1M_5 and V_2M_5. The fourth maximum dry matter weight (73.20 g) was observed in V_2M_3 that was statistically similar to V_1M_3 and V_2M_5. The V_2M_3 treatment produced 52.08% lower dry matter weight compared to V_1M_7 due to no weeding. Uncontrolled weed growth throughout the crop growth caused a yield reduction of 57.6 to 73.2% (Tesfaye *et al*., 2014). On the other hand, the minimum dry matter weight (18.74 g) was measured in V_1M_1 which statistically insignificant with V_2M_1 (27.38 g). The second minimum dry matter production was observed in V_1M_4 (43.12 g) that statistically similar to V_2M_4 (50.08 g). The third minimum dry matter weight (64.75 g) was weighed in V_1M_2 which statistically non-significant with V_2M_2 (66.69 g) and V_2M_3 (73.20 g). The V_1M_2 and V_2M_2 treatments showed 71.92% and 66.92% lower dry matter weight compared to V_1M_7 due to no fertilizer. Bazzaz *et al*. (2008) concluded that application up to 120 kg N ha^{-1} and 1.0 kg B ha^{-1} in wheat significantly increased the dry matter production, leaf area index and crop growth rate.

4.1.9 SPAD value

4.1.9.1 Effects of variety

A statistically significant variation on SPAD value of chlorophyll content was observed by the effect of variety at 70 DAS but at 40 DAS SPAD value didn't significant (Appendix XII & Fig. 17). At 40 DAS, BARI Gom-32 gave maximum SPAD value (48.46) compared to BARI Gom-30 (44.69) but they were statistically insignificant. BARI Gom-32 showed 8.44% higher SPAD value compared to BARI Gom-30. At 70 DAS, BARI Gom-32 also possessed higher SPAD value (52.09) compared to BARI Gom-30 (49.37) and they were statistically significant. BARI Gom-32 showed 5.51% higher SPAD value compared to BARI Gom-30, might be due to its genotypic characters.

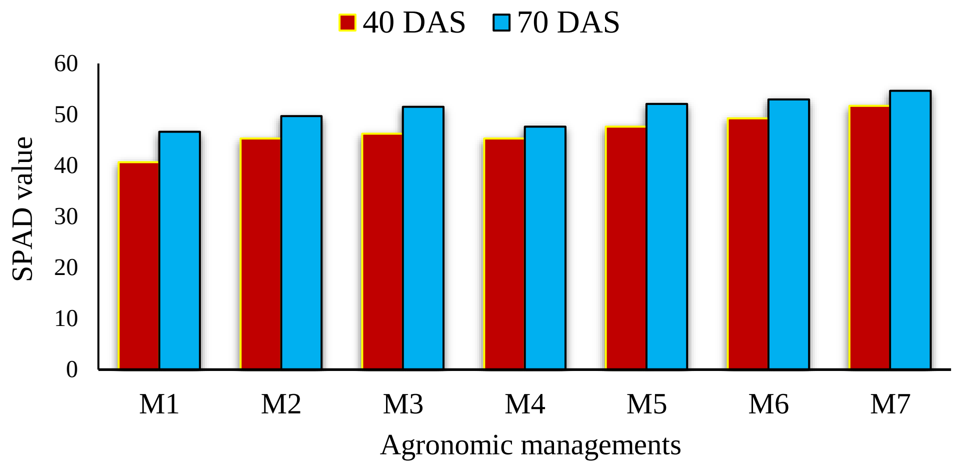


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 17. Effects of variety on SPAD value at different growth stages of wheat ($LSD_{(0.05)}$= 0.238 at 70 DAS).

4.1.9.2 Effects of agronomic managements

Different agronomic managements showed significant differences on SPAD value of chlorophyll content in leaf at different growth stages (Appendix XII & Fig. 18). At 40 DAS, the highest SPAD value was recorded in M_7 (51.72) which was statistically significant from others. The second highest value was observed in M_6 (49.23) that was statistically insignificant with M_5 (47.60). The third highest SPAD value (46.21) was found in M_3 which was statistically similar to M_5. The M_3 treatment showed 11.92% lower SPAD value compared to M_7 due to no weeding. Hakim *et al*. (2013) mentioned that the chlorophyll content (SPAD value) was decreased with increasing the duration of weed interference period. While the lowest SPAD value (40.63) was measured in M_1 which was statistically dissimilar to others. The second lowest SPAD value (45.29) and (45.32) was recorded in M_2 and M_4, respectively and they were statistically non-significant with M_3.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 18. Effects of agronomic managements on SPAD value at different growth stages of wheat ($LSD_{(0.05)}$= 2.105 and 0.637 at 40 and 70 DAS, respectively).

At 70 DAS, the maximum SPAD value was also found in M_7 (54.66) that was statistically different from others. The second maximum value (52.94) was recorded in M_6 which was statistically significant from others. The third maximum SPAD value (52.05) was showed by M_5 which was statistically non-significant with M_3 (51.52). The M_3 treatment showed lower SPAD value compared to M_7. Hakim *et al*. (2013) also found that the chlorophyll content (SPAD value) was decreased with increasing the duration of weed interference period. On the contrary, the lowest SPAD value was recorded in M_1 (46.63) that was statistically dissimilar to others. The second and third lowest (47.63) and (49.70) SPAD value was observed in M_4 and M_2, respectively and they were statistically different from others. The M_4 and M_2 treatments were showed 14.76% and 9.98% lower chlorophyll content compared to M_7 due to no irrigation and fertilizer application, respectively.

4.1.9.3. Interaction of variety and agronomic managements

Interaction effect of variety and agronomic management packages significantly influenced on SPAD value at different growth stages (Appendix XII & Table 9). At 40 DAS, the highest SPAD value was recorded in V_2M_7 (55.48) that was statistically different from others. The second highest SPAD value (51.68) was measured in V_2M_6 which was statistically insignificant with V_2M_5 (47.13) and V_1M_7 (47.97). The third highest SPAD value (47.83) was recorded in V_2M_3 that was statistically similar to V_2M_2, V_1M_6, V_2M_4 and V_1M_5 and also to V_2M_5 and V_1M_7. Whereas the lowest SPAD value was found in V_1M_1 (40.07) which was statistically non-significant with V_2M_1. The second lowest value (43.41) was recorded in V_1M_3 that was statistically insignificant with V_1M_4 and V_1M3 and also with V_2M_1.

At 70 DAS, the highest SPAD value was recorded in V_2M_7 (56.20) which was statistically dissimilar to others. The second highest (54.99) SPAD value was found in V_2M_6 that was also statistically different from others. The third highest SPAD value was measured in V_2M_5 (53.65) which was statistically insignificant with V_1M_7 (53.12) and V_2M_3 (52.96). On the other hand, the lowest SPAD value was found in V_1M_1 (46.34) which was statistically similar to V_2M_1 (46.92). The second lowest (47.25) SPAD value was recorded in V_1M_4 that was statistically non-significant with V_1M_2 and V_2M_1. The third minimum SPAD value was observed in V_2M_4 (48.01) which was also statistically insignificant with V_1M_2 and V_1M_4. From the above discussion, it may conclude that BARI Gom-32 with complete agronomic management showed higher SPAD value compared to BARI Gom-30 with complete managements that helps to produce more dry matter production and ultimately yield.

Table 9. Interaction of variety and agronomic managements on SPAD value of wheat at different growth stages

Treatment combinations	SPAD value at	
	40 DAS	**70 DAS**
V_1M_1	40.07 g	46.34 h
V_1M_2	43.41 ef	47.48 fg
V_1M_3	44.59 def	50.07 e
V_1M_4	43.95 def	47.25 fg
V_1M_5	46.07 cde	50.44 e
V_1M_6	46.79 cde	50.88 e
V_1M_7	47.97 bc	53.12 c
V_2M_1	41.19 fg	46.92 gh
V_2M_2	47.17 cde	51.92 d
V_2M_3	47.83 cd	52.96 c
V_2M_4	46.69 cde	48.01 f
V_2M_5	49.13 bc	53.65 c
V_2M_6	51.68 b	54.99 b
V_2M_7	55.48 a	56.20 a
$LSD_{(0.05)}$	2.977	0.900
CV (%)	3.79	1.05

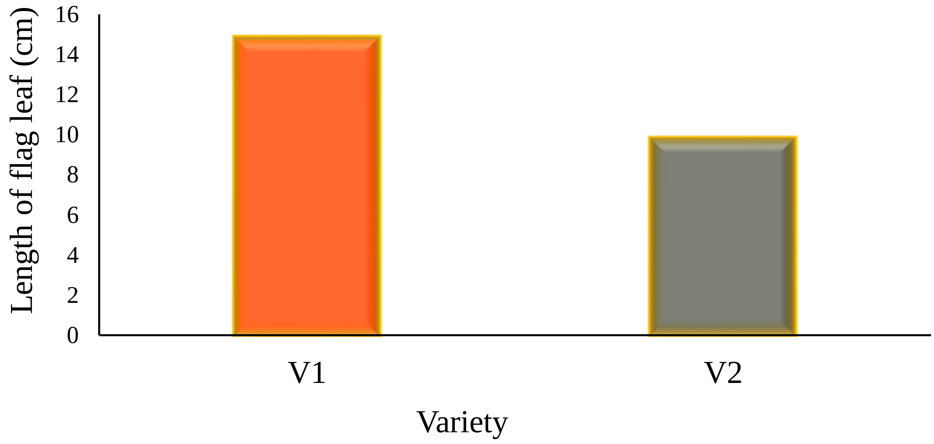
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.1.10 Length of flag leaf

4.1.10.1 Effects of variety

Length of flag leaf was varied significantly by the effects of variety viz. BARI Gom-30 and BARI Gom-32 (Appendix XIII & Fig. 19). BARI Gom-30 and BARI Gom-32 showed (14.82 cm) and (9.81 cm) of flag leaf, respectively and they were statistically significant. The BARI Gom-30 performed 51.07% higher flag leaf length compared to BARI Gom-32. This result was supported by Azad *et al*. (2017) who demonstrated that BARI Gom-30 showed longer flag leaf compared to BARI Gom-32. Al-Musa *et al.* (2012) also found similar findings. They opined that length of flag leaf was varied with variety to variety.

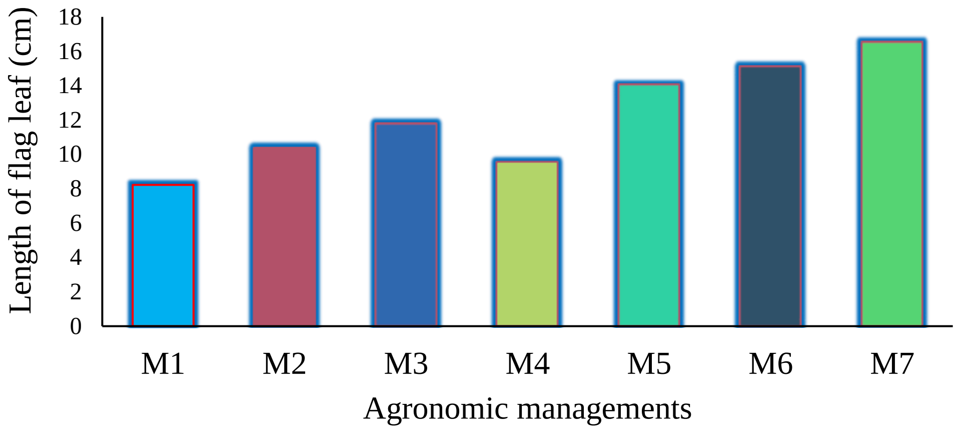


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 19. Effects of variety on flag leaf length of wheat ($LSD_{(0.05)}$= 1.333).

4.1.10.2 Effects of agronomic managements

Length of flag leaf was affected by different agronomic managements and also found statistically significant variation (Appendix XIII & Fig. 20). The longest flag leaf (16.54 cm) was recorded in M_7 which was statistically different from other treatments. The second longest flag leaf (15.11 cm) and (14.05 cm) were measured in M_6 and M_5, respectively and they were statistically insignificant. The M_6 and M_5 treatments reduced length of flag leaf by 9.46% and 17.72% compared to M_7 due to no pest management & thinning, respectively. The flag leaf contributes 60 to 85% to the final grain yield. Yield reduction results if even 5 to 10% of the flag leaf surface is diseased, yield is reduced (Oplinger and Wersman, 1985). The third longest flag leaf was measured in M_3 (11.80 cm) that was statistically dissimilar from others and it showed 40.17% lower flag leaf length compared to M_7 due to no weeding.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 20. Effects of agronomic managements on flag leaf length of wheat ($LSD_{(0.05)}$= 1.315).

On the contrary, the shortest flag leaf was measured in M_1 (8.82 cm) which was statistically insignificant with M_4 (9.53 cm). The M_1 treatment reduced 87.53% length of flag leaf compared to M_7 due to no management. The second shortest flag leaf (10.36 cm) was observed in M_2 that was also statistically similar to M_4. The M_2 and M_4 treatments performed 59.65% and 73.56% lower length of flag leaf compared to M_7 due to no fertilizer and irrigation, respectively.

4.1.10.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed significant variation on flag leaf length (Appendix XIII & Table 10). The highest length of flag leaf was measured in V_1M_7 (20.21 cm) which was statistically insignificant with V_1M_6 (19.11 cm). The second highest flag leaf length (17.29 cm) was recorded in V_1M_5 that was also statistically similar to V_1M_6. The third highest flag leaf length was reported in V_1M_3 which was statistically non-significant with V_2M_7 and V_1M_2. While the lowest length of flag leaf was measured in V_2M_1 (7.71 cm) which was statistically insignificant with V_2M_4 (8.13 cm) and V_2M_2 (8.45 cm). The second lowest flag leaf length (9.61 cm) was reported in V_2M_3 that statistically non-significant with V_1M_1 (9.93 cm) and also with V_2M_4 and V_2M_2. The third lowest flag leaf length was recorded in V_2M_5 (10.81 cm) which was also statistically similar to V_2M_6, V_1M_4, V_1M_1 and V_2M_3. BARI Gom-30 with complete agronomic managements showed 57.03% higher length of flag leaf compared to BARI Gom-32 with complete agronomic managements. BARI Gom-30 with no pest control performed 72.01% higher flag leaf length compared to BARI Gom-32 with no pest control. Larsson (2005) revealed that thrips larvae and adults cause partial or complete coloration of the ears, known as the white ear effect, drying of the flag leaf, partial ear fertilization, and incomplete grain filling. Grain weight losses is about 5-7% in mildly damaged grain, but can reach 15-31% or more in severely damaged grain.

Table 10. Interaction of variety and agronomic managements on flag leaf length of wheat

Treatment combinations	Length of flag leaf (cm)
V_1M_1	9.93 fg
V_1M_2	12.27 cde
V_1M_3	13.99 c
V_1M_4	10.93 def
V_1M_5	17.29 b
V_1M_6	19.11 ab
V_1M_7	20.21 a
V_2M_1	7.71 h
V_2M_2	8.45 gh
V_2M_3	9.61 fg
V_2M_4	8.13 gh
V_2M_5	10.81 ef
V_2M_6	11.11 def
V_2M_7	12.87 cd
$LSD_{(0.05)}$	1.860
CV (%)	8.96

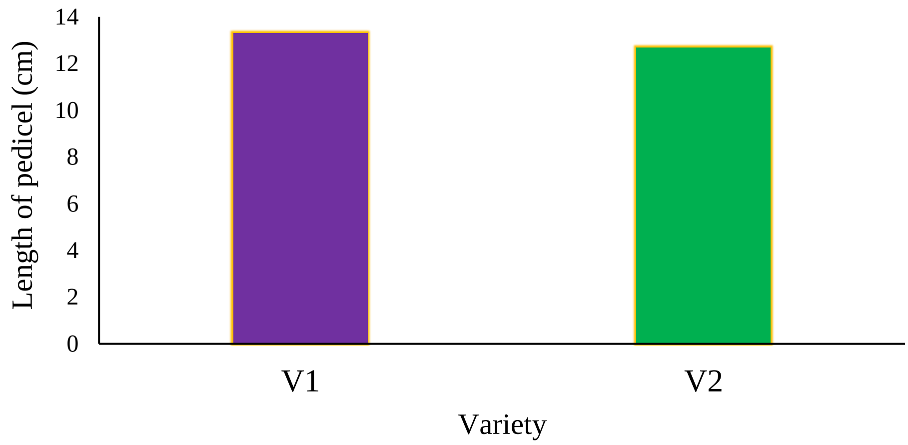
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.1.11 Length of pedicel

4.1.11.1 Effects of variety

Length of pedicel was varied insignificantly by the effects of variety viz. BARI Gom-30 and BARI Gom-32 (Appendix XIII & Fig. 21). Higher length of pedicel (13.30 cm) was measured in BARI Gom-30 compared to BARI Gom-32 (12.68 cm) but they were statistically insignificant. BARI Gom-30 performed 4.89% higher pedicel length compared to BARI Gom-32. This was also supported by the findings of Azad *et al*. (2017). They demonstrated that BARI Gom-30 showed longer pedicel compared to BARI Gom-32.

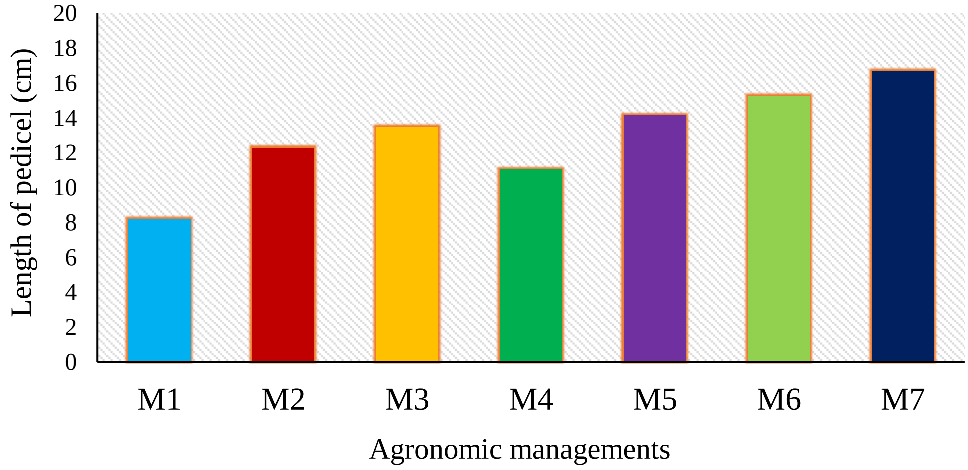


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 21. Effects of variety on pedicel length of wheat.

4.1.11.2 Effects of agronomic managements

Different agronomic managements showed statistically significant variation on length of pedicel of wheat (Appendix XIII & Fig. 22). The maximum length of pedicel was recorded in M_6 (16.56 cm) which was statistically insignificant with M_6 (15.25 cm). The second maximum length of pedicel (14.13 cm) was measured in M_5 that was also statistically non-significant with M_6. The M_6 and M_5 treatments showed 8.59% and 17.20% lower length of pedicel compared to M_7 due to no pest management and thinning, respectively. The finding was supported by the findings of Begum *et al.* (2017). The third maximum pedicel length (13.46 cm) was observed in M_3 that was statistically similar to M_5. The M_3 treatment performed 23.03% lower pedicel length compared to M_7 due to no weeding.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 22. Effects of agronomic managements on length of pedicel of wheat ($LSD_{(0.05)}$= 1.722).

On the other hand, the minimum length of pedicel was found in M_1 (8.19 cm) that was statistically dissimilar to others. The second minimum length of pedicel (11.04 cm) was recorded in M_4 which was statistically insignificant with M_2 (12.28 cm). The M_4 and M_2 treatment showed 51.00% and 35.75% lower length of pedicel compared to M_7 due to no irrigation and fertilizer, respectively. The M_3 treatment performed 23.85% lower pedicel length compared to M_7 due to no weeding.

4.1.11.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed significant variation on pedicel length (Appendix XIII & Table 11). The highest pedicel length (18.20 cm) was observed in V_1M_7 which was statistically similar with V_1M_6 (16.13 cm). The V_1M_6 treatment showed 12.83% lower pedicel length compared to V_1M_7 due to no pest management. The second highest pedicel length (14.93 cm) was measured in V_2M_7 that was statistically insignificant with V_1M_5 (14.73 cm), V_2M_6 (14.36 cm) and also with V_1M_6.

Table 11. Interaction of variety and agronomic managements on pedicel length of wheat

Treatment combinations	Length of pedicel (cm)
V_1M_1	8.18 l
V_1M_2	11.62 f-j
V_1M_3	13.69 c-f
V_1M_4	10.53 i-l
V_1M_5	14.73 bcd
V_1M_6	16.13 ab
V_1M_7	18.20 a
V_2M_1	8.19 l
V_2M_2	12.94 c-i
V_2M_3	13.23 c-h
V_2M_4	11.55 f-k
V_2M_5	13.53 c-g
V_2M_6	14.36 b-e
V_2M_7	14.93 bc
$LSD_{(0.05)}$	2.435
CV (%)	11.13

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

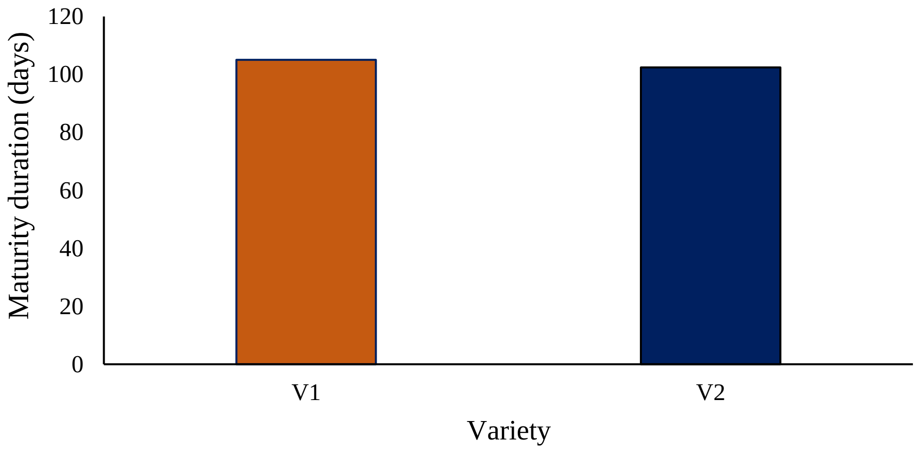
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

The third highest length of pedicel was recorded in V_1M_3 (13.69 cm) which was statistically similar to V_1M_5, V_2M_2, V_2M_3 & V_2M_5 and also to V_2M_7. Whereas, the lowest pedicel length was reported in V_1M_1 (8.18 cm) and V_2M_1 (8.19 cm) and they were statistically insignificant and also with V_1M_4. The second lowest pedicel length (11.55 cm) was measured in V_2M_4 that was statistically dissimilar to others. The remaining all other treatments showed more or less same pedicel length but they were statistically significant.

4.1.12 Maturity duration

4.1.12.1 Effects of variety

In the main effect of variety on maturity duration showed significant variations at 5% level of probability (Appendix XIII & Fig. 23). The higher duration (105.05 days) was required to mature by BARI Gom-30, while the lower duration (102.43 days) by BARI Gom-32 and they were statistically dissimilar. Maturity days were varied to varieties as reported by Kamrozzaman *et al.* (2016) and Irfan *et al*. (2005). The outcomes were also similar to the results of Azad *et al.* (2017). They found BARI Gom-30 and BARI Gom-32 were matured at (100 to 105) and (95 to 105) days, respectively.

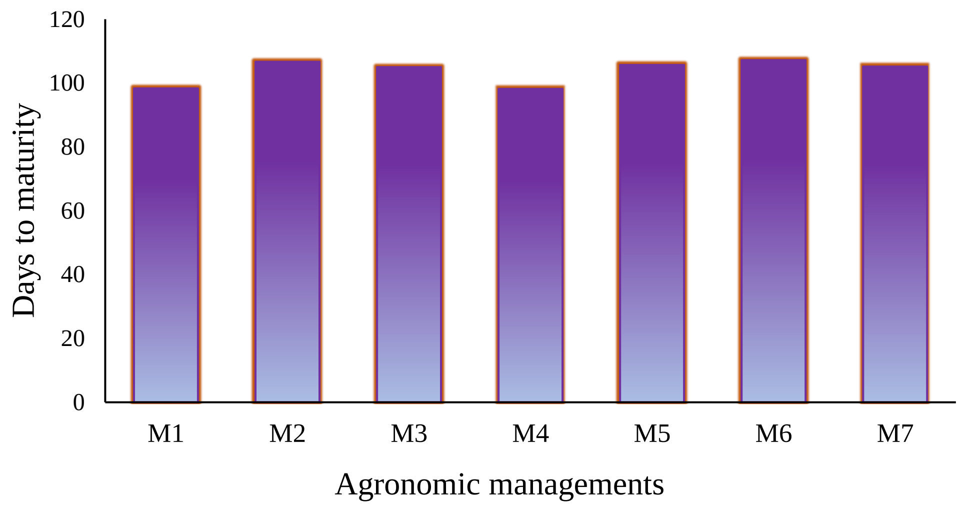


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 23. Effects of variety on maturity days of wheat ($LSD_{(0.05)}$= 1.677).

4.1.12.2 Effects of agronomic managements

Days of maturity was varied significantly by influence of different agronomic managements (Appendix XIII & Fig. 24). The maximum duration (107.17 days) of maturity were required for M_6 treatment which was statistically insignificant with M_2, M_3, M_5 and M_7. The M_7 treatment matured at 105.17 days which was similar to the findings of Azad *et al.* (2017). The M_2 treatment matured at delayed (106.67 days) due to no fertilizer application. But the result was contrary to the findings of Mohan *et al*. (2018), Hameed *et al.* (2003), Matsi *et al*. (2003) and Deldon (2001). They found that maturity days were increased with fertilizer application.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 24. Effects of agronomic managements on maturity duration of wheat ($LSD_{(0.05)}$= 2.629).

While the minimum duration (98.17 days) of maturity were required for M_4 which was statistically insignificant with M_1 (98.56 days). The treatment M_4 matured early due to moisture stress as no irrigation was applied. Islam *et al.* (2018), Islam *et al.* (2015) & Ngwako and Mashiqa (2013) also found similar findings.

4.1.12.3 Interaction of variety and agronomic managements

Maturity duration was showed statistically significant variations by the influence of variety and agronomic managements (Appendix XIII & Table 12). The maximum duration (108.67 days) of maturity was observed in V_1M_3 that statistically similar with V_1M_6, V_1M_2, V_1M_7, V_1M_5, V_2M_6, V_2M_5 and V_2M_2. The second maximum duration required to mature was found in V_2M_7 (103.67 days) that also statistically insignificant with V_1M_7, V_1M_5, V_2M_6, V_2M_5 and V_2M_2. On the other hand, the minimum days of maturity (98.00 days) were observed in V_2M_1 and V_2M_4 and these were statistically non-significant with V_1M_1 and V_1M_4. The second minimum days to maturity (101.33 days) were observed in V_2M_3 that also statistically similar to V_2M_2 and V_2M_7. From the discussion, it was found that without irrigation both the varieties matured earlier. Islam *et al.* (2018), Islam *et al.* (2015) & Ngwako and Mashiqa (2013) were also found similar findings. The remaining all other treatments were showed more or less same days to maturity, but BARI Gom-30 with complete management required more duration compared to BARI Gom-32 with complete agronomic managements.

Table 12. Interaction effects of variety and agronomic managements on maturity duration of wheat

Treatment combinations	Maturity duration (days)
V_1M_1	98.67 d
V_1M_2	108.33 a
V_1M_3	108.67 a
V_1M_4	98.33 d
V_1M_5	106.00 ab
V_1M_6	108.67 a
V_1M_7	106.67 ab
V_2M_1	98.00 d
V_2M_2	105.00 abc
V_2M_3	101.33 cd
V_2M_4	98.00 d
V_2M_5	105.33 ab
V_2M_6	105.67 ab
V_2M_7	103.67 bc
$LSD_{(0.05)}$	3.719
CV (%)	2.13

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

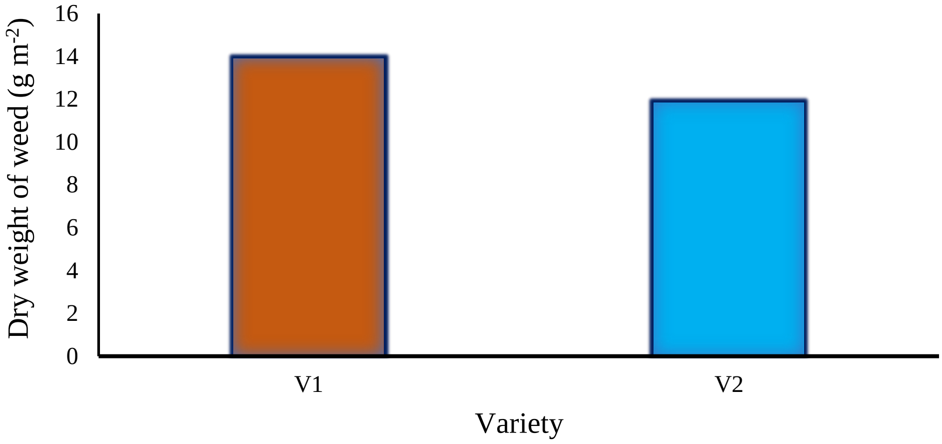
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.2 Data regarding with weed

4.2.1 Dry weight of weed m^{-2}

4.2.1.1 Effects of variety

Dry weight of weed was showed statistically significant variation by the effects of varieties viz. BARI Gom-30 and BARI Gom-32 (Appendix XIV & Fig. 25). The variety BARI Gom-30 possessed higher dry weight of weed (13.9 g) compared to BARI Gom-32 (11.84 g) and they were statistically dissimilar. Although BARI Gom-30 possessed higher dry matter of weed compared to BARI Gom-32, but biological yield (2.94 t ha^{-1}) was higher compared to BARI Gom-32 (2.74 t ha^{-1}). It means that BARI Gom-30 has higher weed competitiveness capacity compared to BARI Gom-32. Shabi *et al.* (2018) showed that BARI Gom-28 and BARI Gom-30 appeared as the most weed competitive varieties (17.8 and 24.9% relative yield losses, respectively) with moderate grain yield. But the outcomes were contrary to the concept of Mahmud (2017). He found dry weight of weed was not significant for variety to variety.

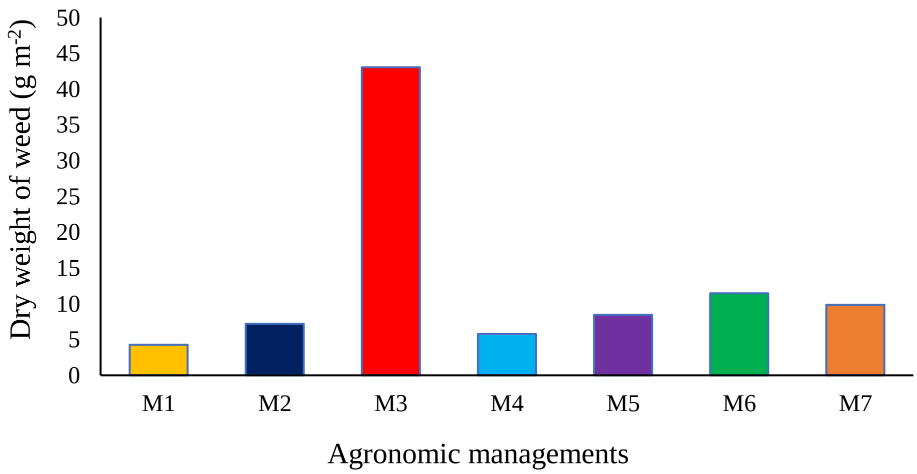


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 25. Effects of variety of wheat on dry weight of weed ($LSD_{(0.05)}$= 1.940).

4.2.1.2 Effects of agronomic managements

Statistically significant variation was observed on dry weight of weed by influence of agronomic managements (Appendix XIV & Fig. 26). The maximum weed dry weight was weighted in M_3 (No weeding) which was statistically different from others. Dry weight of weed biomass varied significantly due to different agronomic managements as reported by Mahmud (2017).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 26. Effects of agronomic managements on dry weight of weed ($LSD_{(0.05)}$= 3.264).

The second maximum weed dry matter (11.46 g) was measured in M_6 that was statistically insignificant with M_5 and M_7. On the other hand, the minimum dry matter of weed was recorded in M_1 (control) which was statistically non-significant with M_2 and M_4. The treatment M_1 showed lower dry weight due to the minimum growth of plant and weed due to starvation, as no management e.g. water, fertilizer etc. applied these in. The remaining treatments showed more or less similar dry weight of weed but they were statistically significant.

4.2.1.3 Interaction of variety and agronomic managements

Dry weight of weed was varied statistically by the interaction of variety and agronomic managements (Appendix XIV & Table 13). The highest dry matter of weed (56.99 g) was measured in V_1M_3 which was statistically different from others.

Table 13. Interaction of variety and agronomic managements on dry weight of weed

Treatment combinations	Dry weight of weed (gm^{-2})
V_1M_1	4.04 g
V_1M_2	6.80 d-g
V_1M_3	56.99 a
V_1M_4	4.29 fg
V_1M_5	6.25 efg
V_1M_6	10.18 cde
V_1M_7	8.73 c-f
V_2M_1	4.50 fg
V_2M_2	7.63 d-g
V_2M_3	29.12 b
V_2M_4	7.26 d-g
V_2M_5	10.67 cde
V_2M_6	12.73 c
V_2M_7	11.00 cd
$LSD_{(0.05)}$	4.617
CV (%)	11.35

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

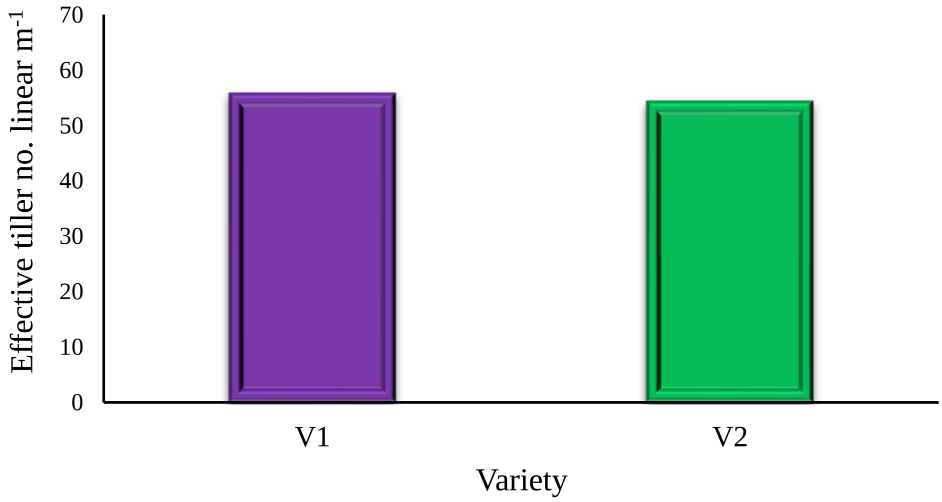
The second highest dry weight of weed was weighted in V_2M_3 (29.12 g) that was statistically dissimilar to others. The V_1M_3 treatment showed 95.71% higher weed dry matter compared to V_2M_3 but finally V_1M_3 performed higher grain yield over the treatment of V_2M_3 that means V_1M_3 had higher weed competitive capacity compared to V_2M_3. The third highest dry matter of weed (12.73 g) was recorded in M_2M_6 that was statistically insignificant with V_1M_6, V_1M_7, V_2M_5 and V_2M_7. On the contrary, the lowest dry weight of weed (4.04 g) was measured in V_1M_1 which was statistically non-significant with V_1M_2, V_1M_4, V_1M_5, V_2M_1, V_2M_2 and V_2M_4. These treatments were performed lowest weed dry matter production due to no management, fertilizer, thinning and irrigation. The remaining treatments were showed more or less same dry matter of weed but they were not statistically similar.

4.3 Yield and yield contributing components

4.3.1 Number of effective tillers linear m^{-1}

4.3.1.1 Effects of variety

A statistically non-significant variation was noticed by the influence of variety on effective tiller number meter^{-1} (Appendix XV & Fig. 27). Although BARI Gom-30 performed higher effective tiller number (55.81) but it was statistically insignificant with BARI Gom-32 (54.38). Azad *et al*. (2017) also found an insignificant effect on effective tiller number hill^{-1} (4-6) by the variety of BARI Gom-30 and BARI Gom-32. Kamrozzaman *et al*. (2016) evaluated the performance of five varieties BARI Gom-21, BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 and found that varieties differed significantly on effective tiller number hill^{-1}.

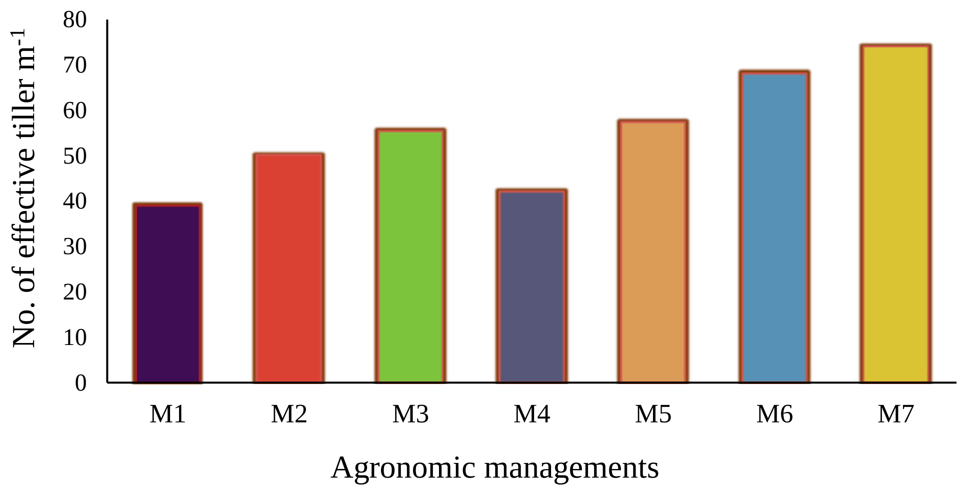


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 27. Effects of variety on effective tiller number linear m^{-1} of wheat.

4.3.1.2 Effects of agronomic managements

Agronomic managements showed a statistically significant variation on the number of effective tillers of wheat (Appendix XV & Fig. 28). The maximum effective tiller number was counted in M_7 (74.00) which was statistically insignificant with M_6 (68.00). The second maximum effective tiller number (57.33) was recorded in M_5 that was statistically similar to M_3.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 28. Effects of agronomic managements on effective tiller number linear m^{-1} of wheat ($LSD_{(0.05)}$= 7.118).

The M_3 and M_5 showed 33.74% and 29.08% lower effective tiller number compared to M_7 due to no weeding and thinning practice, respectively. Kaur *et al.* (2018) and Sultana *et al.* (2012) reported that severe crop weed competition which resulted in reduction in the expression of yield components such as effective tillers m^{-2} (347.2) and (246.70), respectively. Whereas, the minimum number of effective tiller (39.00) was found in M_1 which was statistically non-significant with M_4 (42.00). The M_7 treatment performed 76.19% higher effective tiller number compared to M_4 (no irrigation). Islam *et al.* (2018) proclaimed that maximum number of effective tillers (5.00 $hill^{-1}$) was produced by application of irrigation water compared to no irrigation. Mishra and Padmakar (2010) also observed that progressively increase in number of irrigations from 1 to 4 increased various yield contributing characters viz., effective tillers m^{-2}, ear length, no. of grains ear^{-1} and seed weight. The second minimum effective tiller number was counted in M_2 (50.00) that was statistically also similar to M_3. The M_2 treatment decreased effective tiller number by 48.00% compared to M_7 due to no fertilizer. Kumar *et al.* (2018) gave their opinion that application of 125% RDF produced significantly higher number of effective tillers m^{-2}.

4.3.1.3 Interaction of variety and agronomic managements

Interaction effect of variety and agronomic managements showed statistically significant differences on number of effective tillers (Appendix XV & Table 14). The highest number of effective tillers m^{-1} (74.67) was counted in V_1M_7 which was statistically insignificant with V_2M_7, V_1M_6 and V_2M_6. The second highest effective tillers number was recorded in V_1M_5 (61.33) that was also statistically non-significant with V_1M_6 and V_2M_6. The V_1M_5 and V_2M_6 were reduced effective tiller number by 21.75% and 14.30% compared to V_1M_7 due to no thinning and pest management, respectively. Fengqi *et al.* (2013) stated that infested plants were all significantly impacted by english grain aphid infestation. Third highest effect tillers (57.33) were enumerated in V_1M_3 that was statistically similar to V_1M_5 and V_2M_6.

Table 14. Interaction of variety and agronomic managements on effective tiller number linear m^{-1} of wheat

Treatment combinations	No. of effective tiller m^{-1}
V_1M_1	37.33 h
V_1M_2	49.33 efg
V_1M_3	57.33 cde
V_1M_4	40.00 gh
V_1M_5	61.33 bcd
V_1M_6	70.67 ab
V_1M_7	74.67 a
V_2M_1	40.67 gh
V_2M_2	50.67 d-g
V_2M_3	53.33 def
V_2M_4	44.00 fgh
V_2M_5	53.33 def
V_2M_6	65.33 abc
V_2M_7	73.33 a
$LSD_{(0.05)}$	10.066
CV (%)	10.84

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

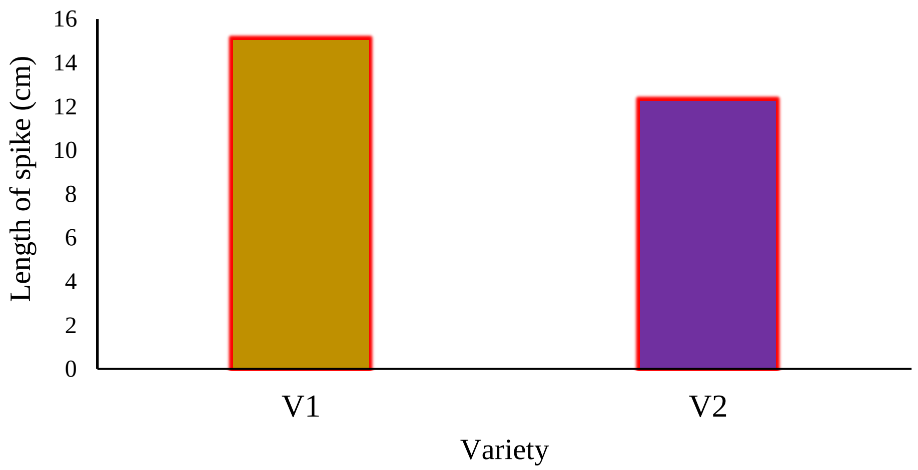
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

The V_1M_3 treatment showed 34.95% lower tiller number compared to V_1M_7 due to no weeding. Singh and Saha (2001) found that weed control plots showed greater number of effective tillers and fertile spikelets as compared to weedy check (no weeding). The V_2M_2 treatment showed 47.37% lower effective tiller number compared to V_1M_7 due to no fertilizer application. Similar result was also found by Singh *et al.* (2015) who reported that using of fertilizer was superior over no fertilizer application in relation to plant height, dry weight, effective tillers, yield and yield attributes and protein content in grains of wheat. On the other hand, the lowest effective tillers number m^{-1} (37.33) was found in V_1M_1 that was statistically insignificant with V_1M_4 (40.00), V_2M_1 (40.67) and V_2M_4 (44.00). The treatments V_1M_4 and V_2M_4 showed lower effective tiller number by 86.68% and 69.70% compared to V_1M_7 due to no irrigation. Uddin *et al.* (2016) and Ahmed (2006) recorded that enough irrigation water and nutrient supply can increase yield up to 70% in Bangladesh. Irrigation frequency has a significant influence on the growth and yield of wheat. In term of effective tillers production, BARI Gom-30 with complete management was better compared to BARI Gom-32 with complete management. On the other hand, irrigation considered as most important agronomic management that reduced effective tiller number of 40.43% and 40.00% for BARI Gom-30 and BARI Gom-32, respectively compared to that of complete management.

4.3.2 Length of spike

4.3.2.1 Effects of variety

Length of spike across the varieties was significantly affected by 1% level of probability that ranged from 12.26 cm to 15.04 cm (Appendix XV & Fig. 29). The higher spike length (15.04 cm) was measured in BARI Gom-30 which was statistically significant with BARI Gom-32 (12.26 cm). BARI Gom-30 performed 25.61% higher spike length compared to BARI Gom-32.



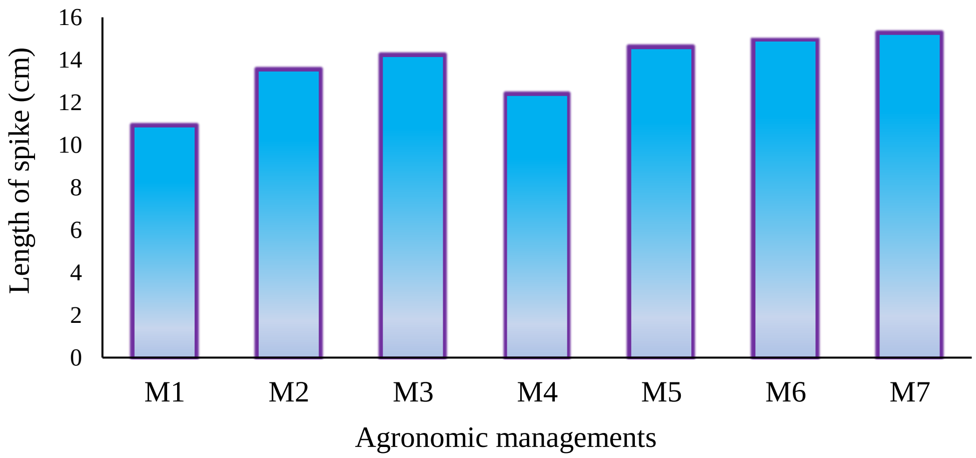
V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 29. Effects of variety on spike length of wheat ($LSD_{(0.05)}$= 0.225).

Azad *et al*. (2017) found similar result where they opined that BARI Gom-30 performed higher spike length (16.00 cm) compared to BARI Gom-32 (13.00 cm) that ultimately increased the yield. Kamrozzaman *et al*. (2016) evaluated the performance of five varieties BARI Gom-21, BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 and also found that varieties differed significantly on spike length.

4.3.2.2 Effects of agronomic managements

Statistically significant variation was noticed on spike length by the influence of different agronomic managements (Appendix XV & Fig. 30). Maximum length of spike (15.22 cm) was recorded from M_7 which was statistically at par with M_6 (14.91 cm) and M_5 (14.55 cm). Second maximum length of spike was measured in M_3 (14.18 cm) which also statistically similar to M_5 (14.55 cm). On the contrary, minimum length of spike (10.87 cm) was found in M_1 that statistically dissimilar to others. Second minimum spike length was observed in M_4 (12.35 cm) which was statistically different from others and this treatment decreased spike length by 23.24% compared to M_7 due to no irrigation. Three irrigations in wheat field, plants showed the greater performance on spike length (17.28 cm) was also found by Islam *et al*. (2018). Spike length was drastically decreased without irrigation was also reported by Atikullah (2014).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 30. Effects of agronomic managements on spike length of wheat ($LSD_{(0.05)}$=0.734).

The third minimum length of spike (13.50 cm) was found from M_2 treatment that was statistically insignificant with M_3. Length of spike was reduced by 12.74% in M_2 treatment in case of no fertilizer application. Arif *et al*. (2017) evaluated that maximum spike length (14.01 cm) and minimum spike length (8.16 cm) were performed with fertilizer and without fertilizer, respectively.

4.3.2.3 Interaction of variety and agronomic managements

Interaction between variety and management practices was found significant in respect of length of spike (Appendix XV & Table 15). The longest spike (16.53 cm) was obtained from V_1M_7 followed by V_1M_6 (16.05 cm), V_1M_5 (15.93 cm) and V_1M_3 (15.80 cm) which were statistically non-significant. The second longest spike (15.18 cm) was measured from V_1M_2 which was also statistically similar to V_1M_6 (16.05 cm), V_1M_5 (15.93 cm) and V_1M_3 (15.80 cm). The third highest spike length was recorded in V_1M_4 (13.95 cm) followed by V_2M_7, V_2M_6 and V_2M_5 which were statistically similar. On the other hand, the shortest spike length (9.88 cm) was found in V_2M_1 that was statistically similar to V_2M_4 (10.74 cm). The second shortest spike was obtained from V_2M_2 (11.82 cm) which was statistically insignificant with V_1M_1 and V_2M_3. The results indicated that BARI Gom-30 with complete management was possessed higher length of spike compared to BARI Gom-32 with complete management.

Table 15. Interaction of variety and agronomic managements on spike length of wheat

Treatment combinations	Length of spike (cm)
V_1M_1	11.85 e
V_1M_2	15.18 b
V_1M_3	15.80 ab
V_1M_4	13.95 c
V_1M_5	15.93 ab
V_1M_6	16.05 ab
V_1M_7	16.53 a
V_2M_1	9.88 f
V_2M_2	11.82 e
V_2M_3	12.55 de
V_2M_4	10.74 f
V_2M_5	13.16 cd
V_2M_6	13.77 c
V_2M_7	13.90 c
$LSD_{(0.05)}$	1.038
CV (%)	4.51

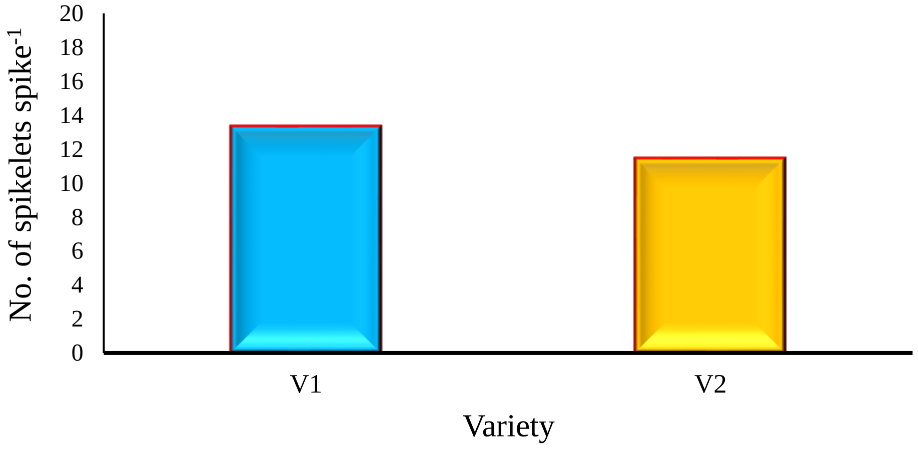
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.3 Number of spikelets spike^{-1}

4.3.3.1 Effects of variety

Analysis of variance of number of spikelets spike^{-1} showed highly significant differences between the tested wheat varieties (Appendix XVI & Fig. 31). The higher number of spikelets spike^{-1} (13.33) was recorded from BARI Gom-30, whereas the lower number (11.48) from BARI Gom-32. BARI Gom-30 performed 16.11% higher number of spikelets spike^{-1} compared to BARI Gom-32. This variation was found due to their genetic makeup. Similar result was also supported by Azad *et al*. (2017) and Kamrozzaman *et al*. (2016) where they found that BARI Gom-30 having the capacity of higher spikelets spike^{-1} compared to BARI Gom-32.

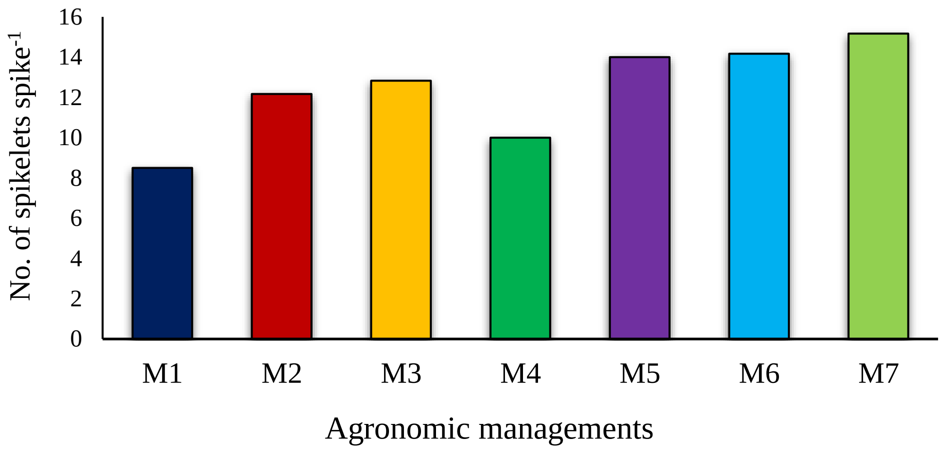


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 31. Effects of variety on number of spikelets spike^{-1} of wheat (LSD$_{(0.05)}$= 0.615).

4.3.3.2 Effects of agronomic managements

Number of spikelets spike^{-1} was significantly influenced by the agronomic management and it was ranged from 8.50 to 15.17 (Appendix XVI & Fig. 32). Significantly the maximum number of spikelets spike^{-1} (15.17) which was statistically different from others. The second maximum number of spikelets spike^{-1} was counted from M_6 (14.17) that followed by M_5 (14.00) (no thinning) and they were statistically insignificant. Li *et al*. (2016) and Xu *et al*. (2015) reported that under dense plant the grain number at the 3rd and 4th grain positions and the 1st and 2nd grain positions of the basal and top spikelets decreased. Gendua *et al*. (2009) also reported that the number of spikelets spike^{-1} changes under different plant densities. Whereas the lowest number of spikelets spike^{-1} (8.50) was noted in M_1 which was statistically different from others. The second lowest (10.00) number of spikelets spike^{-1} was recorded in M_4 that was statistically different with others. The M_4 treatment reduced number of spikelets spike^{-1} by 51.70% compared to M_7 by the effects of no irrigation.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 32. Effects of agronomic managements on number of spikelets spike^{-1} of wheat ($LSD_{(0.05)}$= 0.791).

Islam *et al.* (2015) reported that number of spikelets spike^{-1} increased with irrigation and they found maximum number of spikelets spike^{-1} (19.00) with 3 irrigations. The third lowest number of spikelets spike^{-1} (12.17) was obtained from M_2 which was statistically non-significant with M_3 (12.83). The M_2 treatment reduced number of spikelets spike^{-1} by 24.65% compared to M_7 due to no fertilizer application. Arif *et al.* (2017) showed that number of spikelets spike^{-1} was decreased in case of no fertilizer application. Ashraf *et al.* (2011) also found similar effect. But Rahman (2005) didn't support this finding, rather stated that there was no significant response of different levels of nitrogen in case of number of effective spikelets spike^{-1}. The M_3 treatment also reduced number of spikelets spike^{-1} compared to M_7 due to no weed management. The similar results were reported by Sultana *et al.* (2012).

4.3.3.3 Interaction of variety and agronomic managements

The number of spikelets spike^{-1} was significantly influenced by the interaction effect of variety and agronomic management practices (Appendix XVI & Table 16). The maximum number of spikelets spike^{-1} (16.33) was obtained from V_1M_7 which was statistically dissimilar to others. The second maximum spikelets number (15.00) was recorded in V_1M_3 followed by V_1M_6 (14.67), V_1M_5 (14.33) and V_2M_7 (14.00) and they were statistically similar. The third maximum number of spikelets spike^{-1} (13.67) was observed in V_2M_5 and V_2M_6 these were also statistically insignificant with V_1M_6, V_1M_5 and V_2M_7. On the contrary, the minimum number of spikelets spike^{-1} was obtained from V_1M_1 (8.33) which was statistically insignificant with V_2M_1 and V_2M_4. The second minimum number of spikelets spike^{-1} (10.67) was noted in V_2M_3 followed by V_2M_2 (11.00) and V_1M_4 (11.33) and they were statistically similar. The third minimum number of spikelets spike^{-1} (13.33) was recorded in V_1M_2 that was statistically also similar to V_2M_5, V_2M_6, V_1M_5 and V_2M_7.

The results indicated that there were genotypic differences in number of spikelets spike^{-1} was greatly influenced followed by agronomic management. BARI Gom-30 with all managements showed higher number of spikelets spike^{-1} compared to BARI Gom-32 with complete agronomic managements.

Table 16. Interaction of variety and agronomic managements on the number of spikelets spike^{-1} of wheat

Treatment combinations	Number of spikelets spike^{-1}
V_1M_1	8.33 f
V_1M_2	13.33 d
V_1M_3	15.00 b
V_1M_4	11.33 e
V_1M_5	14.33 bcd
V_1M_6	14.67 bc
V_1M_7	16.33 a
V_2M_1	8.67 f
V_2M_2	11.00 e
V_2M_3	10.67 e
V_2M_4	8.67 f
V_2M_5	13.67 cd
V_2M_6	13.67 cd
V_2M_7	14.00 bcd
$LSD_{(0.05)}$	1.118
CV (%)	5.35

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

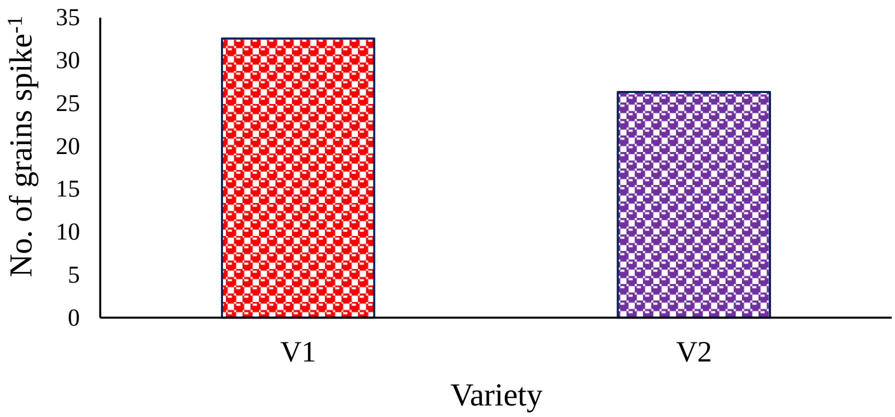
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.4 Number of grains spike^{-1}

4.3.4.1 Effects of variety

The number of grains spike^{-1} is an important component for yield of wheat. Number of grains spike^{-1} across the varieties was significantly affected by 1% level of probability and it was ranged from 26.33 to 32.57 (Appendix XVI & Fig. 33). The BARI Gom-30 showed higher (32.57) number of grains spike^{-1} compared to BARI Gom-32 (26.33). The BARI Gom-30 increased 23.70% more number of grains spike^{-1} than BARI Gom-32. This variation was found might be its genetical variations.

Azad *et al.* (2017) also found similar finding where they recorded number of grains spike^{-1} (45 to 50) and (42 to 47) from BARI Gom-30 and BARI Gom-32, respectively. Kamrozzaman *et al*. (2016) and Al-Musa *et al.* (2012) also mentioned that number of grains spike^{-1} was significantly influenced by the varieties.

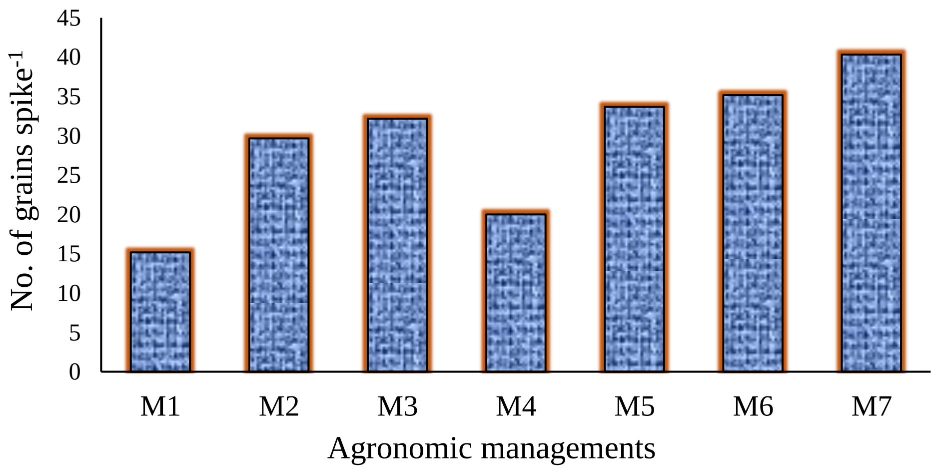


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 33. Effects of variety on number of grains spike^{-1} of wheat (LSD$_{(0.05)}$= 1.786).

4.3.4.2 Effects of agronomic managements

Number of grains spike^{-1} was significantly influenced by the agronomic managements and it was ranged from 15.17 to 40.33 (Appendix XVI & Fig. 34). The highest number of grains spike^{-1} was obtained from M_7 (40.33) because all agronomic managements were done here which was statistically dissimilar to others.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 34. Effects of agronomic managements on number of grains spike^{-1} of wheat (LSD$_{(0.05)}$= 1.817).

The second highest number of grains spike^{-1} found in M_6 (35.17) that was statistically insignificant with M_5 (33.67). The M_6 treatment decreased 14.67% number of grains by the effects of no pest management. This was also supported by the findings of Fengqi *et al.* (2013). The M_5 treatment showed 19.78% lower number of grains spike^{-1} compared to M_7 due to no thinning operation. Li *et al.* (2016) explored that the grain number varied significantly at different spikelet and grain positions among wheat grown at different plant densities. The third highest number of grains spike^{-1} (32.17) was counted in M_3 which was also statistically similar to M_5. The M_3 treatment performed 25.37% lower number of grains spike^{-1} compared to M_7 due to no weed management. This finding was also recommended by Acker (2010) and Sultana (2009). On the while, the lowest number of grains spike^{-1} (15.17) was found in M_1 which was statistically different from others. The second lowest grain number was recorded in M_4 (20.00) that was also statistically different from others. The M_4 treatment showed lower number of grains spike^{-1} compared to M_7 due to no irrigation. Islam *et al.* (2018) and Abdul-Jabbar *et al.* (2016) were also found similar results. They opined that the water pressure could reduce the number of grains in the spike. The third minimum number of grains spike^{-1} (29.67) was noted from M_2 treatment which was statistically dissimilar to others. The M_2 treatment performed 35.93% lower number of grains in the spike compared to M_7 by reason of no fertilizer application. Mohan *et al.* (2018) and Asif *et al.* (2012) also found similar results and reported that the treatment of integrated nitrogen application (50% FYM + 50% urea) showed maximum grains spike^{-1} (50 grains). Their findings were also supported by Gul *et al.* (2011).

4.3.4.3 Interaction of variety and agronomic managements

The number of grains spike^{-1} was significantly influenced by the interaction of variety and agronomic management and it was ranged from 15.00 to 44.00 (Appendix XVI & Table 17). The maximum number of grain (44.00) was obtained from V_1M_7 which was statistically significant with others. The second maximum number of grains was recorded in V_1M_6 (39.33) that showed similarity with V_1M_5 (37.67) and V_2M_7 (36.67). The third maximum number of grains (35.33) was recorded in V_1M_3 which was also similar with V_1M_5 and V_2M_7. On the contrary, the minimum number grains spike^{-1} was counted in V_1M_1 (15.00) that was statistically insignificant with V_2M_1 and V_2M_4. The second minimum number of grains spike^{-1} (24.00) was reported in V_1M_4 that was statistically similar to V_2M_2 (29.00). The third minimum number of grains was recorded in V_2M_5 (29.67) which showed similarity with V_2M_6 and V_2M_3. This result showed that performance of BARI Gom-30 with complete managements was better compared to BARI Gom-32 with complete agronomic managements.

Table 17. Interaction of variety and agronomic managements on the number of grains spike^{-1} of wheat

Treatment combinations	Number of grains spike^{-1}
V_1M_1	15.00 h
V_1M_2	32.67 d
V_1M_3	35.33 c
V_1M_4	24.00 g
V_1M_5	37.67 bc
V_1M_6	39.33 b
V_1M_7	44.00 a
V_2M_1	15.33 h
V_2M_2	26.67 fg
V_2M_3	29.00 ef
V_2M_4	16.00 h
V_2M_5	29.67 e
V_2M_6	31.00 de
V_2M_7	36.67 bc
$LSD_{(0.05)}$	2.570
CV (%)	5.18

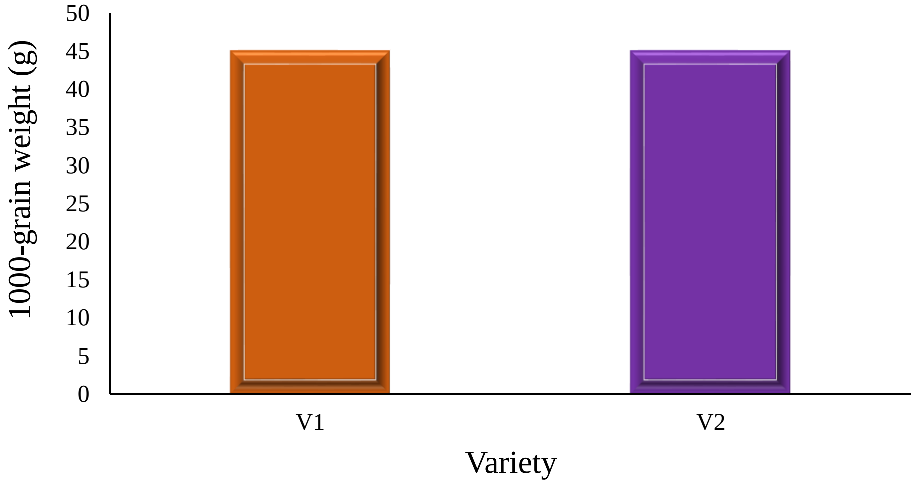
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.5 1000-grain weight

4.3.5.1 Effects of variety

In the main effect of variety on 1000-grain weight showed the non-significant variation at 5% level of probability (Appendix XVII & Fig. 35). The higher 1000-grain weight (45.14 g) was obtained from BARI Gom-30, whereas the lower (45.12 g) from BARI Gom-32 and they were statistically non-significant. Similar result was also found by Mahmud (2017). But the outcomes were contrary to the concept of Azad *et at.* (2017). They determined that 1000-grain weight of BARI Gom-30 was lower (44 to 48 g) compared to BARI Gom-32 (50 to 58 g). This was also supported by the findings of Din *et al*. (2018), Kamrozzaman *et al*. (2016) and Ali *et al.* (2011). They gave their opinion that weight of 1000-grain was significantly varied by variety to variety.

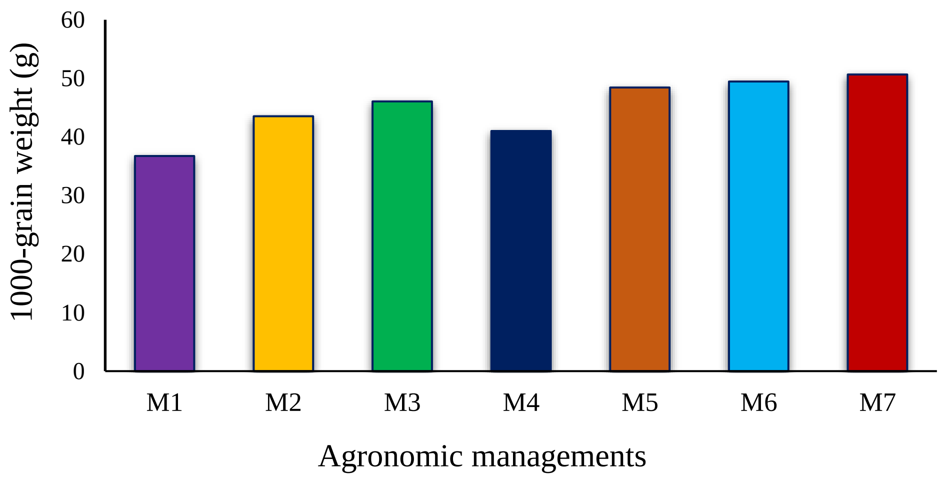


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 35. Effects of variety on 1000-grain weight of wheat.

4.3.5.2 Effects of agronomic managements

Weight of 1000-grain was varied statistically by the effects of different agronomic managements and it was ranged from 36.73 g to 50.66 g (Appendix XVII & Fig. 36). The maximum 1000-grain weight (50.66 g) was measured in M_7 (complete management) which was statistically insignificant with M_6 (no pesticides). Dissimilar result was reported by Begum *et al.* (2017) who observed that weight of 1000-grain was varied significantly by infestation of pests. The second maximum 1000-grain weight was weighted from M_5 (48.44 g) that was also statistically insignificant with M_6 and it decreased by 4.58% compared to M_7 due to no thinning operation. The finding was supported the results of Begum *et al.* (2017) and Roy (2007).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 36. Effects of agronomic managements on 1000-grain weight of wheat ($LSD_{(0.05)}$= 1.209).

The third maximum 1000-grain weight (46.06 g) was recorded in M_3 that was statistically significant from others and it decreased weight by 9.99% compared to M_7 treatment for the reason of no weed management. Kaur *et al.* (2018), Sultana *et al.* (2012) and Sultana (2009) were also observed similar outcomes. Kaur *et al.* (2018) found that weed free field was performed higher 1000 grain weight and enhanced the yield up to 43.1% over weedy check. Whereas, the minimum 1000-grain weight was recorded from M_1 (36.73 g) which was statistically dissimilar from other treatments. The second minimum 1000-grain weight (41.01 g) was measured in M_4 that was statistically different from others and it showed 23.53% lower weight compared to M_7 treatment. The similar results were also found by Mueen-ud-din *et al*. (2015) and Maqsood *et al*. (2010). They opined that weight of 1000-grain was greatly decreased without irrigation facilities. The third minimum 1000-grain weight was obtained from M_2 (43.53 g) which was statistically significant from other treatment and it performed 16.38% lower weight compared to M_7 due to no fertilizer application. Mohan *et al*. (2018), Arif *et al*. (2017) and Klikocka *et al*. (2016) were also observed similar findings.

4.3.5.3 Interaction of variety and agronomic managements

Weight of 1000-grain was showed statistically significant differences by the influence of variety and agronomic managements (Appendix XVII & Table 18). The highest 1000-grain weight (51.40 g) was recorded in V_1M_7 that was statistically insignificant with V_1M_6 and V_2M_7. The second highest 1000-grain weight was measured from V_2M_6 (48.98 g) that was statistically similar to V_1M_5 and V_2M_5 and also to V_1M_6 and V_2M_7. The treatments no pesticides and no thinning performed statistically similar 1000-grain weight. The third highest 1000-grain weight (47.10 g) was weighed in V_2M_3 which was statistically similar to V_1M_5 and V_2M_5. BARI Gom-32 performed higher 1000-grain weight with no weed management compared to BARI Gom-30 with no weeding. On the other hand, the lowest 1000-grain weight was measured in V_2M_1 (36.68 g) and V_1M_1 (36.80 g) and they were statistically non-significant. The second lowest 1000-grain weight (40.45 g) was observed in V_1M_4 followed by V_2M_4 (41.57 g) and they showed statistically similarity. The third lowest 1000-grain weight (43.20 g) was obtained from V_2M_2 which was also similar to V_2M_4 (41.57 g). In all cases of treatment except no weeding and irrigation, BARI Gom-30 performed numerically higher 1000-grain weight compared to BARI Gom-32, but BARI Gom-32 showed better performance in the treatments of no weeding and irrigation compared to BARI Gom-30. These results were also supported the findings of Mahmud (2017) and Das (2016) who found similar results on interaction of variety and agronomic managements. From the discussion, it can conclude that BARI Gom-30 and BARI Gom-32 performed more or less similar on 1000-grain weight for the effect of variety and agronomic managements.

Table 18. Interaction of variety and agronomic managements on 1000-grain weight of wheat

Treatment combinations	1000-grain weight (g)
V_1M_1	36.80 h
V_1M_2	43.87 de
V_1M_3	45.02 d
V_1M_4	40.45 g
V_1M_5	48.48 bc
V_1M_6	49.94 ab
V_1M_7	51.40 a
V_2M_1	36.68 h
V_2M_2	43.20 ef
V_2M_3	47.10 c
V_2M_4	41.57 fg
V_2M_5	48.39 bc
V_2M_6	48.98 b
V_2M_7	49.91 ab
$LSD_{(0.05)}$	1.710
CV (%)	2.25

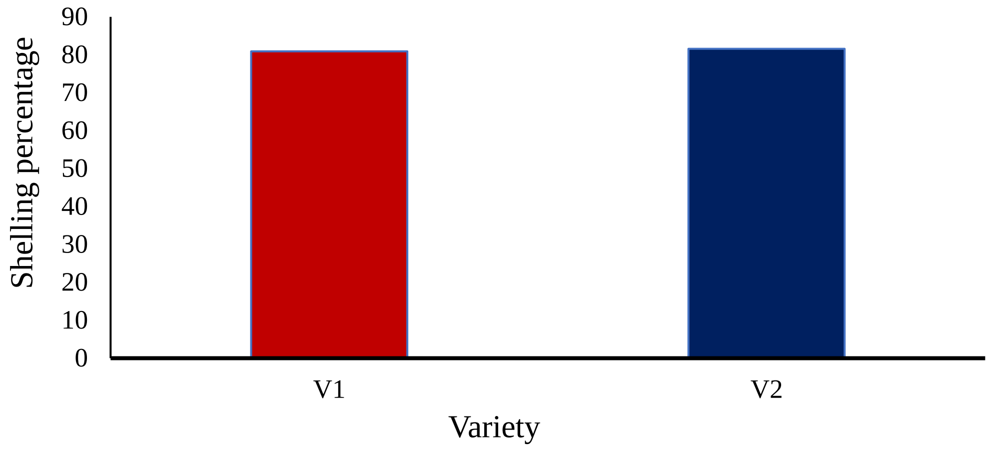
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.6 Shelling percentage

4.3.6.1 Effects of variety

A statistically non-significant variation was noticed by the influence of variety on shelling percentage (Appendix XVII & Fig. 37). The higher shelling percentage (81.58) was recorded from BARI Gom-32, whereas the lower shelling percentage (80.91) from BARI Gom-30 but they were statistically non-significant. But the outcomes were contrary to the concept of Azad *et al*. (2017). They determined that shelling percentage of BARI Gom-30 was lower compared to BARI Gom-32 and they varied significantly.

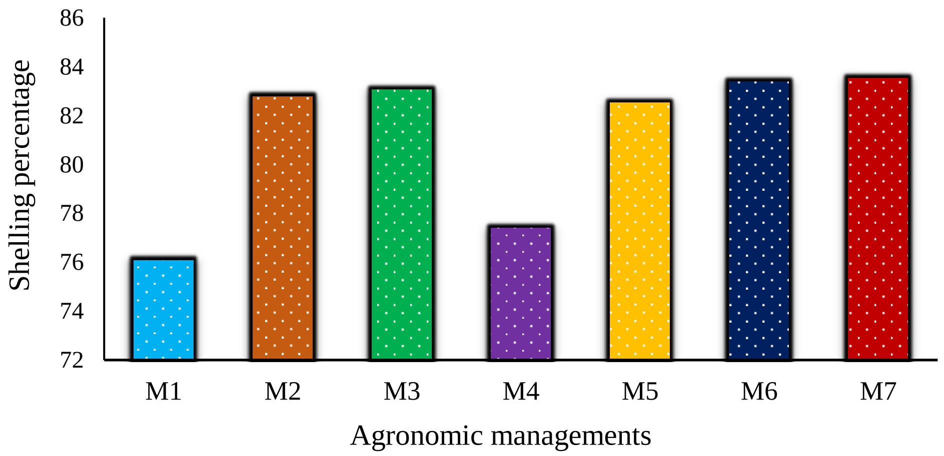


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 37. Effects of variety on shelling percentage of wheat.

4.3.6.2 Effects of agronomic managements

Different agronomic managements showed statistically significant variations on shelling percentage and it was ranged from 76.08% to 83.53% (Appendix XVII & Fig. 38). The maximum shelling percentage (83.53) was recorded from M_7 which was statistically insignificant with M_2 (82.78%), M_3 (83.05%), M_5 (82.52%) and M_6 (83.38%). On the contrary, the minimum shelling percentage was obtained from M_1 (76.08%) followed by M_4 (77.39%) and they were statistically similar. From the discussion, the results were found that no irrigation treatment showed significant variation on shelling percentage with M_7 and it decreased shelling percentage by 7.93% compared to M_7.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 38. Effects of agronomic managements on shelling percentage of wheat ($LSD_{(0.05)}$= 1.988).

4.3.6.3 Interaction of variety and agronomic managements

Shelling percentage was showed statistically significant differences by the influence of variety and agronomic managements (Appendix XVII & Table 19). The maximum shelling percentage (84.22) was obtained from V_2M_7 which was statistically insignificant with all other treatments except V_1M_1, V_1M_4, V_2M_1 and V_2M_4. Whereas, the minimum shelling percentage (75.85) was recorded in V_2M_1 that was statistically non-significant with V_1M_1, V_1M_4 and V_2M_4. From the discussion, the results were found that no irrigation treatment showed significant variation on shelling percentage with V_2M_7 and it decreased shelling percentage by 11.03% compared to M_7. The remaining all treatments performed more or less similar irrespective of varieties with complete agronomic managements.

Table 19. Interaction effects of variety and agronomic managements on shelling percentage of wheat

Treatment combinations	Shelling percentage (%)
V_1M_1	76.31 b
V_1M_2	82.25 a
V_1M_3	83.64 a
V_1M_4	76.61 b
V_1M_5	82.91 a
V_1M_6	81.88 a
V_1M_7	82.77 a
V_2M_1	75.85 b
V_2M_2	83.32 a
V_2M_3	83.42 a
V_2M_4	78.15 b
V_2M_5	82.14 a
V_2M_6	83.99 a
V_2M_7	84.22 a
$LSD_{(0.05)}$	2.811
CV (%)	2.05

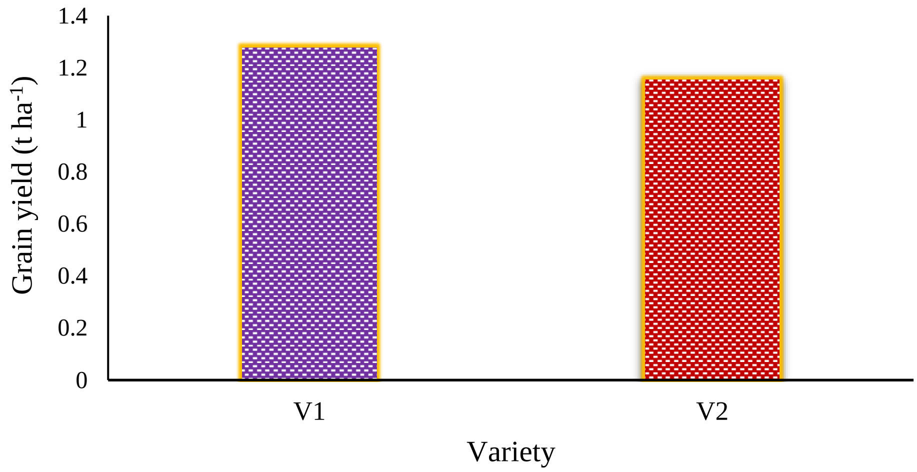
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.7 Grain yield

4.3.7.1 Effects of variety

In the main effect of variety on grain yield showed the non-significant variation at 1% level of probability (Appendix XVIII & Fig. 39). The BARI Gom-30 and BARI Gom-32 performed grain yield of 1.28 t ha^{-1} and 1.15 t ha^{-1}, respectively and they showed statistically insignificant effects. The BARI Gom-30 gave numerically higher grain yield but it was statistically similar to BARI Gom-32. Similar result was also assessed by Azad *et al.* (2017). They noticed that BARI Gom-30 and BARI Gom-32 performed grain yield (4.5 to 5.5 t ha^{-1}) and (4.6 to 5.0 t ha^{-1}), respectively but they were statistically similar. But this outcome was contrary to the findings of Kamrozzaman *et al*. (2016) and Al-Musa *et al.* (2012).



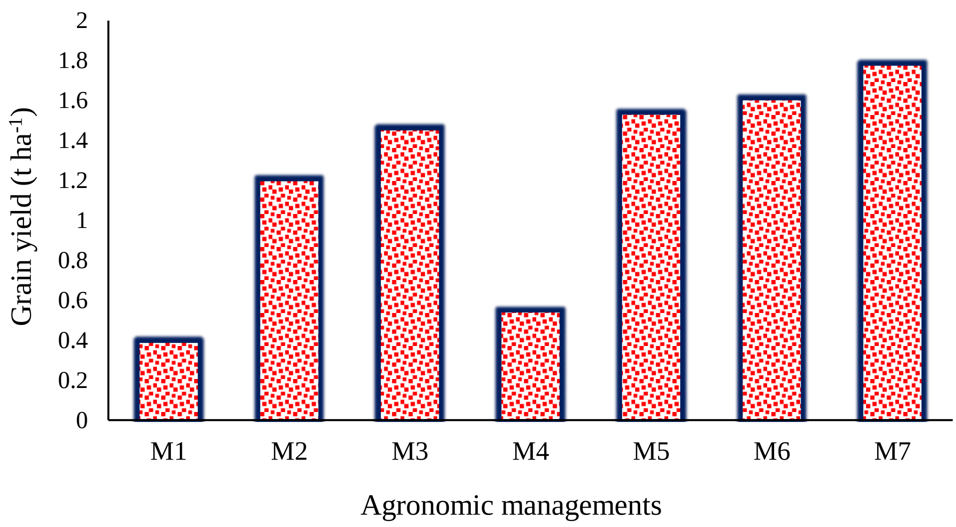
V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 39. Effects of variety on grain yield of wheat.

4.3.7.2 Effects of agronomic managements

Different agronomic managements showed a statistically significant differences on grain yield of wheat and it was ranged from 0.39 t ha^{-1} to 1.78 t ha^{-1} (Appendix XVIII & Fig. 40). The highest grain yield (1.78 t ha^{-1}) was obtained from M_7 plot which was statistically different from others. The second highest grain yield was observed in M_6 (1.61 t ha^{-1}) and it was statistically dissimilar to others. The M_6 plot was decreased grain yield by 10.70% compared to M_7 because of no pest management. Duyn (2005) reported that yield reductions of 10 to 20% are typical in infested commercial fields of wheat by pests. The third highest grain yield (1.53 t ha^{-1}) was measured from M_5 plot which was statistically significant with others and it reduced yield by 15.95% compared to M_7 treatment by the influence of no thinning operation. But the outcomes were contrary to the concept of Yang *et al*. (2019) and Dai *et al*. (2014). They found that increasing planting density from 135 to 405 plants m^{-2} has been shown to significantly increase grain yield.

Whereas, the lowest grain yield (0.39 t ha^{-1}) was found in M_1 which was statistically different from others. The second lowest yield was recorded in M_4 (0.54 t ha^{-1}) that was statistically dissimilar to others. The M_4 treatment showed lowest grain yield except M_1 due to no irrigation applying. The result agreed with the findings of Uddin *et al.* (2016) and Islam *et al*. (2016). They reported that about 30% of wheat production was lost due to lack of irrigation water. Chouhan *et. al*. (2015) also observed that a slightly reduction of 10.8% in the grain yield of wheat because of severe water deficit during the growing stages.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 40. Effects of agronomic managements on grain yield of wheat ($LSD_{(0.05)}$= 0.060).

The third minimum yield was recorded in M_2 (1.20 t ha^{-1}) which was statistically different from others and it decreased yield by 48.16% compared to M_7 the reason of no fertilizer application. Similar trends were observed by Klikocka *et al*. (2016), Hayat *et al*. (2015) and Zahoor (2014). They stated that grain yield of wheat was increased significantly by the application of recommended fertilizers. The fourth minimum grain yield (1.45 t ha^{-1}) was found in M_3 which was statistically dissimilar to others. The M_3 treatment reduced grain yield by 22.25% compared to M_7 due to no weed management. Sateesh *et al*. (2018) indicated that controlling weeds resulted in significant increase in grain yield compared to weed check. The increase ranged from 24.4% under hand weeding at 30 days and 50 DAS to 44.5% under weed free conditions.

4.3.7.3 Interaction of variety and agronomic managements

Grain yield was varied significantly by the interaction of variety and agronomic managements and it was ranged from 0.39 t ha^{-1} to 1.88 t ha^{-1} (Appendix XVIII & Table 20). The maximum grain yield (1.88 t ha^{-1}) was obtained from V_1M_7 treatment which was statistically significant from others. The second maximum yield was recorded in V_2M_7 (1.67 t ha^{-1}) that showed statistically similarity with V_1M_6 (1.66 t ha^{-1}) and it was third maximum grain yield performer. The fourth maximum grain yield (1.57 t ha^{-1}) was noted from V_1M_5 followed by V_2M_5 (1.50 t ha^{-1}) and V_2M_6 (1.55 t ha^{-1}) and they were statistically insignificant. On the contrary, the minimum grain yield was obtained from V_2M_1 (0.39 t ha^{-1}) that was statistically insignificant with V_1M_1 (0.39 t ha^{-1}). The second minimum yield (0.52 t ha^{-1}) was recorded in V_2M_4 which was statistically significant with other treatments.

Table 20. Interaction of variety and agronomic managements on grain yield of wheat

Treatment combinations	Grain yield (t ha^{-1})
V_1M_1	0.39 l
V_1M_2	1.38 h
V_1M_3	1.48 efg
V_1M_4	0.57 j
V_1M_5	1.57 d
V_1M_6	1.66 bc
V_1M_7	1.88 a
V_2M_1	0.39 l
V_2M_2	1.02 i
V_2M_3	1.43 f
V_2M_4	0.52 jk
V_2M_5	1.50 def
V_2M_6	1.55 de
V_2M_7	1.67 b
$LSD_{(0.05)}$	0.086
CV (%)	4.17

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

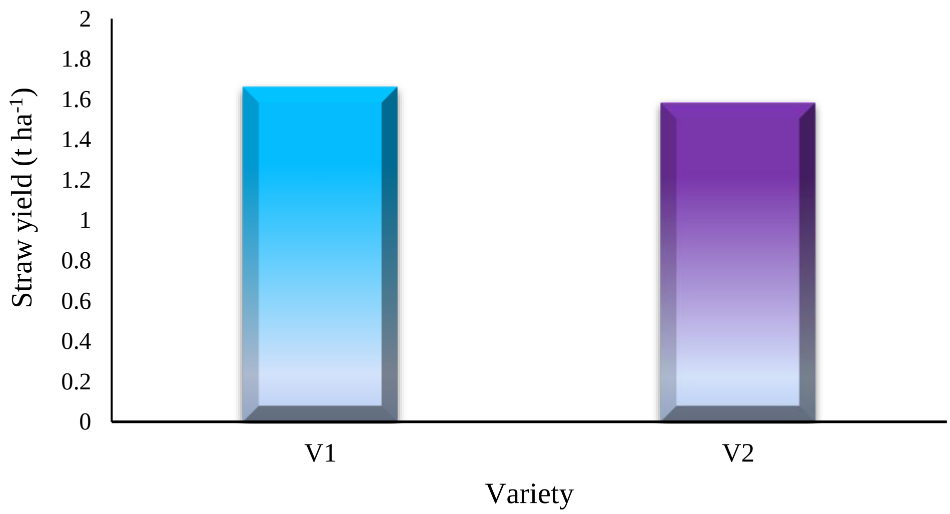
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

The third minimum grain yield (0.57 t ha^{-1}) was reported in V_1M_4 that was also statistically similar to V_2M_4. The fourth minimum yield was observed in V_2M_1 (1.02 t ha^{-1}) which was statistically dissimilar to other treatments. The remaining all other treatments showed more or less same grain yield by the influence of variety and agronomic managements. The results indicated that there were genotypic differences in grain yield might be due to genetic makeup of the varieties and agronomic managements. BARI Gom-30 performed 12.37% higher grain production compared to BARI Gom-32 with complete agronomic managements. Similar grain yield was also recorded by Azad *et at*. (2017), Mahmud (2017) and Das (2016). Both the variety showed lower yield with complete managements compared to potential yield of these variety. This might be due to the geographical location of the experimental site that not suitable for commercial cultivation of wheat.

4.3.8 Straw yield

4.3.8.1 Effects of variety

Straw yield was varied numerically for the variety; BARI Gom-30 (1.66 t ha^{-1}) and BARI Gom-32 (1.58 t ha^{-1}) but not statistically significant (Appendix XVIII & Fig. 41). The variety BARI Gom-30 showed 4.96% higher straw yield compared to BARI Gom-32 but they were statistically similar. This finding was also supported by Azad *et al.* (2017). They demonstrated that BARI Gom-30 performed higher straw yield compared to BARI Gom-32. But the findings were contrary to the finding of Kamrozzaman *et al.* (2016) and Al-Musa *et al.* (2012).

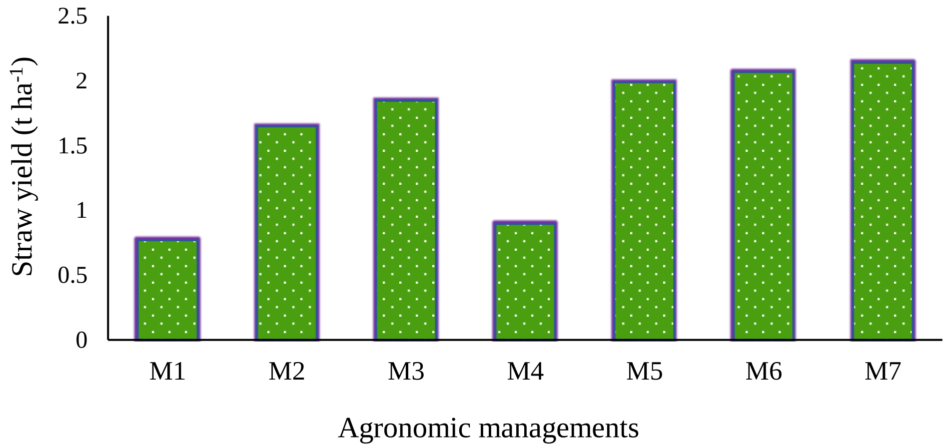


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 41. Effects of variety on straw yield of wheat.

4.3.8.2 Effects of agronomic managements

Agronomic management practices showed a statistically significant variations on straw yield of wheat and it was ranged from 0.77 t ha^{-1} to 2.14 t ha^{-1} (Appendix XVIII & Fig. 42). The highest straw yield was obtained from M_7 (2.14 t ha^{-1}) followed by M_6 (2.07 t ha^{-1}) but they showed similarity statistically. The M_6 treatment showed 3.40% lower straw yield compared to M_7 because of no pest management. Similar result was also found by Larsson (2005) who revealed that grain and straw weight losses was about 5-7% in mildly damaged grain by pest. The second highest straw yield (1.99 t ha^{-1}) was recorded in M_5 which was also statistically similar with M_6. The M_5 treatment performed 7.48% lower straw yield compared to M_7 due to no thinning. But the outcome was contrary to the findings of Begum *et al*. (2017) and Roy (2007). They announced that higher number of plants $meter^{-2}$ was performed higher straw yield. And third highest straw yield was recorded in M_3 (1.85 t ha^{-1}) that was statistically different from other treatments and it decreased straw yield by 15.81% compared to M_7 due to no weed management. This result coincided with the findings of Kaur *et al.* (2018), Singh (2014) and Sultana *et al.* (2012) who observed that lower grain and straw yield was produced with weedy check.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 42. Effects of agronomic managements on straw yield of wheat ($LSD_{(0.05)}$= 0.088).

4.3.8.3 Interaction of variety and agronomic managements

Straw yield was varied significantly by the influence of variety and agronomic managements (Appendix XVIII & Table 21). The highest straw yield (2.22 t ha^{-1}) was obtained from V_1M_7 followed by V_1M_6 (2.13 t ha^{-1}) and they were statistically insignificant. Both the treatments showed more or less similar straw yield because of pest attack in the experiment field was negligence. The second highest straw yield was recorded in V_2M_7 (2.05 t ha^{-1}) which was also statistically insignificant with V_1M_6.

The third highest straw yield (2.00 t ha^{-1}) was noted from V_2M_6 that was statistically non-significant with V_1M_5, V_2M_5 and V_2M_7. On the contrary, the lowest straw yield (0.76 t ha^{-1}) was observed in V_1M_1 followed by V_2M_1 (0.77 t ha^{-1}) and V_2M_4 (0.89 t ha^{-1}) and they were statistically insignificant. The second lowest straw yield was noted from V_1M_4 (0.90 t ha^{-1}) that was also statistically insignificant with V_2M_4. The third and fourth lowest straw yield (1.55 t ha^{-1}) and (1.75 t ha^{-1}) were obtained from V_2V_2 and V_1M_2, respectively and they showed statistically dissimilarity.

Table 21. Interaction of variety and agronomic managements on straw yield of wheat

Treatment combinations	Straw yield (t ha^{-1})
V_1M_1	0.76 l
V_1M_2	1.75 hi
V_1M_3	1.86 fg
V_1M_4	0.90 k
V_1M_5	2.00 cde
V_1M_6	2.13 ab
V_1M_7	2.22 a
V_2M_1	0.77 l
V_2M_2	1.55 j
V_2M_3	1.83 gh
V_2M_4	0.89 kl
V_2M_5	1.98 c-f
V_2M_6	2.00 cd
V_2M_7	2.05 bc
$LSD_{(0.05)}$	0.125
CV (%)	4.57

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

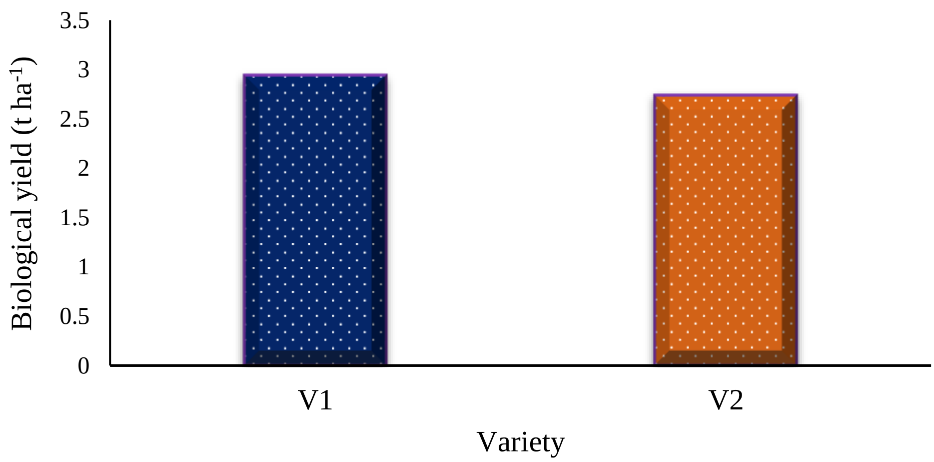
V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

The remaining all other treatments were showed more or less same straw yield but statistically significant. From the interaction of variety and agronomic managements results BARI Gom-30 with complete managements performed higher straw yield compared to BARI Gom-32 with same agronomic practice. Similar result was also found by Mahmud (2017) and Das (2016).

4.3.9 Biological yield

4.3.9.1 Effects of variety

In the main effect of variety on biological yield showed the non-significant variation at 5% level of probability (Appendix XIX & Fig. 43). The variety BARI Gom-30 produced higher biological yield numerically (2.94 t ha^{-1}) compared to BARI Gom-32 (2.74 t ha^{-1}) but they were statistically non-significant. BARI Gom-30 performed 7.33% higher biological yield compared to BARI Gom-32. The result also supported by Azad *et al*. (2017) and Mahmud (2017). They found that biological yield didn't show statistically significant variation in term of variety. But the outcomes were contrary to the statement of Din *et al.* (2018), Kamrozzaman *et al*. (2016) and Das (2016). They opined that biological yield was varied statistically by the influence of variety.

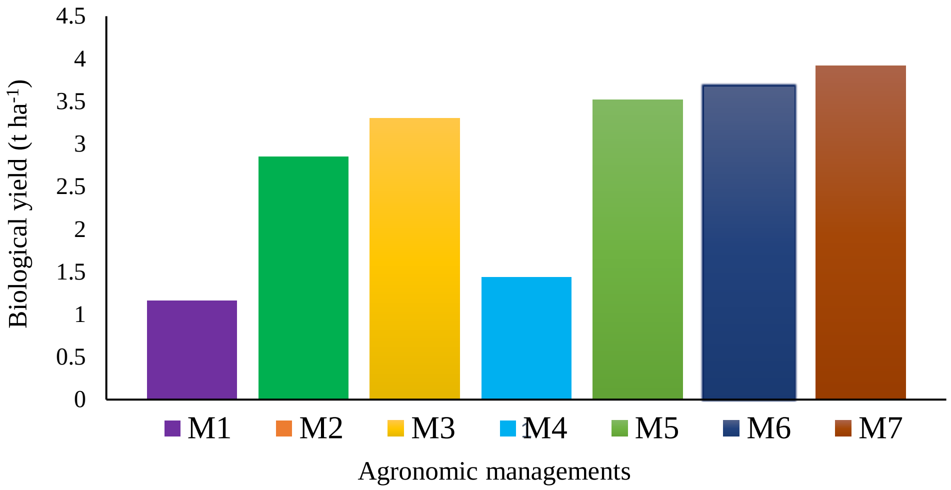


V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 43. Effects of variety on biological yield of wheat.

4.3.9.2 Effects of agronomic managements

Statistically significant variation was observed on biological yield by the influence of different types of agronomic management (Appendix XIX & Fig. 44). The biological yield was varied from 1.16 t ha^{-1} to 3.92 t ha^{-1}. The highest biological yield (3.92 t ha^{-1}) was obtained from M_7 which was statistically significant from other treatments. The second highest biological yield was recorded from M_6 (3.67 t ha^{-1}) that was statistically different and it decreased biological yield by 6.59% compared to M_7 due to no pest management. This result supported the findings of Fengqi *et al.* (2013). The third maximum biological yield (3.52 t ha^{-1}) was noted from M_5 which showed statistically dissimilarity with others. The treatment M_5 decreased biological yield by 11.17% compared to M_7 because of no thinning operation. This was contradictory to the findings of Begum *et al.* (2017) and Roy (2007), who opined that biological yield was increased with maximum plant density. No weed management reduced 18.65% biological yield as compared to complete management of M_7. Zahoor *et al*. (2012) and Sujoy *et al.* (2006) also found similar outcomes. They found that biological yield was decreased with the increasing of weed infestation and period.



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 44. Effects of agronomic managements on biological yield of wheat ($LSD_{(0.05)}$= 0.129).

While the lowest biological yield (1.16 t ha^{-1}) was recorded in M_1 which was statistically dissimilar to other treatments. The second lowest biological yield was measured in M_4 (1.44 t ha^{-1}) that was statistically different from others. The treatment M_4 (no irrigation but all other management) reduced biological yield drastically compared to other treatments except M_1. Islam *et al.* (2018), Islam *et al.* (2015), Kabir *et al.* (2009) and Gupta *et al.* (2001) found similar results and showed that biological yield increased significantly with irrigation. The third lowest biological yield (2.85 t ha^{-1}) was noted in M_2 which was statistically significant from others and it was decreased biological yield by 37.48% compared to M_7 for the reason of no fertilizer application. Kumar *et al.* (2018), Khan *et al.* (2014) and Gul *et al.* (2011) also found similar findings.

4.3.9.3 Interaction of variety and agronomic managements

Biological yield varied significantly by the effects of variety and agronomic managements and it was ranged from 1.16 t ha^{-1} to 4.10 t ha^{-1} (Appendix XIX & Table 22). The highest biological yield obtained from V_1M_7 (4.10 t ha^{-1}) which was statistically significant from others. The second highest biological yield (3.79 t ha^{-1}) was obtained from V_1M_6 followed by V_2M_7 (3.73 t ha^{-1}) and they were statistically insignificant. The third and fourth highest biological yield was found in V_1M_5 (3.57 t/ha) that statistically non-significant with V_2M_6 and V_2M_7. On the other hand, the lowest biological yield (1.16 t ha^{-1}) was noted from V_1M_1 that followed by V_2M_1 (1.16 t ha^{-1}) and they were statistically non-significant. The second lowest biological yield was recorded in V_2M_4 (1.40 t ha^{-1}) and V_1M_4 (1.48 t ha^{-1}) and they were statistically insignificant.

The third lowest biological yield (2.57 t ha^{-1}) was noted from V_2M_2 which was statistically different from other treatments. The remaining all other treatments performed more or less similar biological yield but they were statistically dissimilar. The results indicated that BARI Gom-30 with complete agronomic managements produced higher biological yield compared to BARI Gom-32 with same managements. Similar results were also observed by Mahmud (2017) and Das (2016).

Table 22. Interaction effects of variety and agronomic managements on biological yield of wheat

Treatment combinations	Biological yield (t ha^{-1})
V_1M_1	1.16 k
V_1M_2	3.13 gh
V_1M_3	3.33 ef
V_1M_4	1.48 j
V_1M_5	3.57 cd
V_1M_6	3.79 b
V_1M_7	4.10 a
V_2M_1	1.16 k
V_2M_2	2.57 i
V_2M_3	3.27 fg
V_2M_4	1.40 j
V_2M_5	3.48 de
V_2M_6	3.55 c
V_2M_7	3.73 bc
$LSD_{(0.05)}$	0.183
CV (%)	3.82

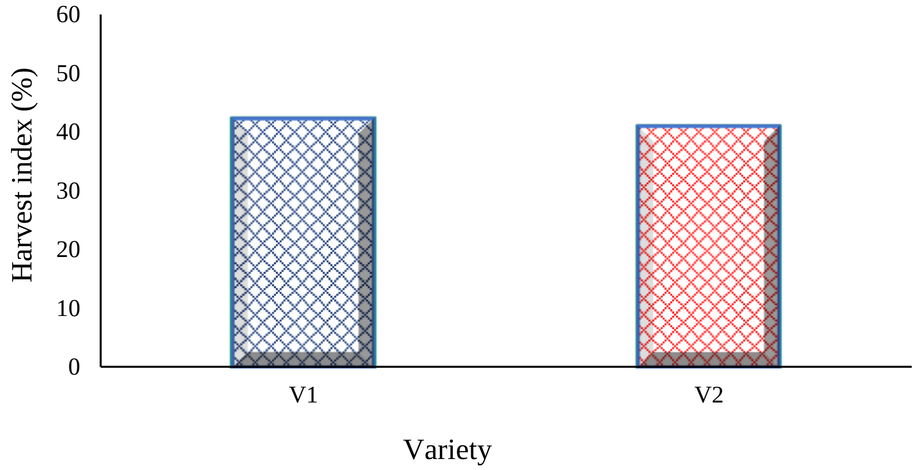
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

Here, V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

4.3.10 Harvest index

4.3.10.1 Effects of variety

Harvest index across the varieties was significantly affected by 5% level of probability (Appendix XIX & Fig. 45). The maximum harvest index (42.14%) was obtained from BARI Gom-30, whereas the minimum (40.78%) from BARI Gom-32 and they were statistically significant. BARI Gom-30 performed 3.34% higher harvest index compared to BARI Gom-32. The results indicated that there were genotypic differences in harvest index might be due to genetic makeup of the varieties which was reported by Das (2016) and Azad *et al.* (2017). But the outcomes were contrary to the findings of Mahmud (2017) and Irfan *et al.* (2005). Non-significant differences in the mean values were found as a result of dates of sowing, genotypes and interaction between dates and genotypes.



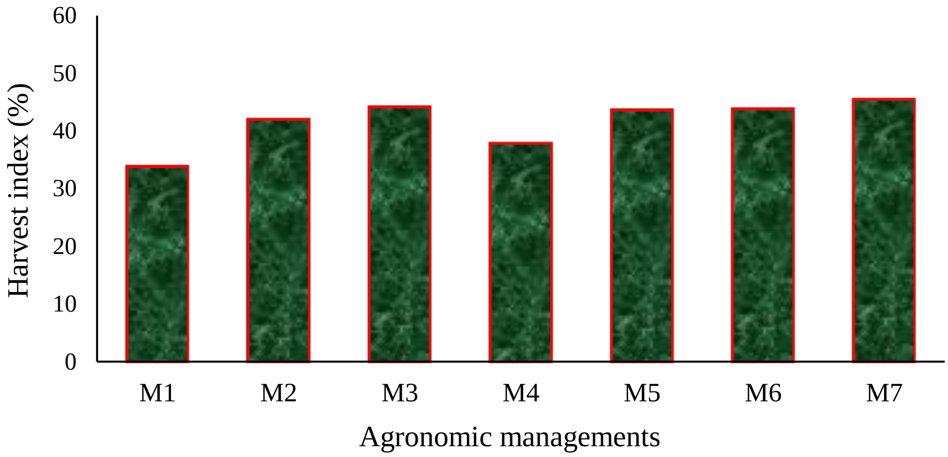
V_1= BARI Gom-30 and V_2= BARI Gom-32

Figure 45. Effects of variety on harvest index of wheat ($LSD_{(0.05)}$= 0.716).

4.3.10.2 Effects of agronomic managements

Different agronomic managements showed statistically significant variations on harvest index and it was ranged from 33.74% to 45.40% (Appendix XIX & Fig. 46). The maximum harvest index (45.40%) was obtained from M_7 treatment followed by M_3 (44.08%) and they were statistically insignificant. The M_3 treatment performed higher harvest index after M_7, but this finding was contrary to results of Mustari *et al.* (2014), Sultana (2009), Hossain (2008) and Sujoy *et al.* (2006). They found maximum harvest index in fully weed managed field. The second maximum harvest index (43.74%) was recorded in M_6 which was statistically non-significant with M_5 and M_3. The M_6 treatment showed lower harvest index compared to M_7 by 3.80% due to no pest management. The M_5 treatment showed 4.27% lower harvest index compared to M_7 treatment because of no thinning operation. The finding was also supported by Roy (2007).

On the contrary, the minimum harvest index (33.74%) was noted from M_1 that was statistically different from others. The second minimum harvest index was recorded in M_4 (37.79%) which was statistically dissimilar to others and it decreased harvest index by 20.13% compared to M_7 for the reason of no irrigation. Similar findings were also found by Islam *et al*. (2018), Islam *et al*. (2015) and Ngwako and Mashiqa (2013). The third minimum harvest index (41.94%) was observed in M_2 that was also statistically significant from other treatments and it reduced harvest index by 8.26% compared to M_7 because of no fertilizer application. The result was also similar with the findings of Mohan *et al.* (2018), Arif *et al*. (2017) and Hira (2009).



M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

Figure 46. Effects of agronomic managements on harvest index (%) of wheat ($LSD_{(0.05)}$= 1.502).

4.3.10.3 Interaction effects of variety and agronomic managements

Interaction effect of variety and agronomic managements showed statistically significant differences on harvest index (Appendix XIX & Table 23). The highest harvest index (45.87%) was obtained from V_1M_7 and it was superior numerically compared to others but statistically insignificant with V_2M_7 (44.94%), V_1M_3 (44.27%), V_1M_2 (44.20%), V_1M_5 (43.91%), V_2M_3 (43.89%) and V_1M_6 (43.84%). The second highest harvest index was recorded in V_2M_6 (43.63%) which was statistically similar with V_2M_5 (43.17%) and also too previously mentioned last six treatments. On the other hand, the lowest harvest index was noted in V_2M_1 (33.37%) followed by V_1M_1 (34.10%) and they showed statistically similarity themselves. Similar findings were also found by Mahmud (2017) and Das (2016). They found lowest harvest index in no agronomic management with varietal variation. The second lowest harvest index (36.79%) was recorded in V_2M_4 followed by V_1M_4 (38.79%) and they were statistically non-significant. Both the treatments decreased harvest index by 24.66% and 18.24%, respectively compared to V_1M_7 due to no irrigation apply.

The third lowest harvest index was observed in V_2M_2 (39.67%) which was also statistically similar with V_1M_4. These results showed that BARI Gom-30 with complete management performed statistically similar harvest index to BARI Gom-32 with complete agronomic managements. Mahmud (2017) and Das (2016) were also found similar results on interaction of variety and agronomic managements.

Table 23. Interaction effects of variety and agronomic managements on harvest index of wheat

Treatment combinations	Harvest index (%)
V_1M_1	34.10 e
V_1M_2	44.20 ab
V_1M_3	44.27 ab
V_1M_4	38.79 cd
V_1M_5	43.91 ab
V_1M_6	43.84 ab
V_1M_7	45.87 a
V_2M_1	33.37 e
V_2M_2	39.67 c
V_2M_3	43.89 ab
V_2M_4	36.79 d
V_2M_5	43.17 b
V_2M_6	43.63 b
V_2M_7	44.94 ab
$LSD_{(0.05)}$	2.124
CV (%)	3.04

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability.

V_1: BARI Gom-30, V_2: BARI Gom-32, M_1: Control (no management), M_2: No fertilizer but all other managements, M_3: No weeding but all other managements, M_4: No irrigation but all other managements, M_5: No thinning but all other managements, M_6: No pesticides but all other managements and M_7: Complete management (recommended).

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2018 to March, 2019 to study the effects of different agronomic managements on growth and yield of wheat. The experiment comprised of two factors. Factor A: Variety: 2 levels;V_1 -BARI Gom-30, V_2 -BARI Gom-32; Factor B: Agronomic managements: 7 levels; No management (control)- M_1; No fertilizer but all other managements- M_2; No weeding but all other managements- M_3; No irrigation but all other managements- M_4; No thinning but all other managements- M_5; No pesticides but all other managements- M_6 and Complement management (recommended)- M_7. The experiment was laid out in Split plot design with three replications having variety in the main plot and agronomic managements in sub-plots. Significant variation was recorded for data on dry matter weight of weed and different growth and yield contributing characters and yield of wheat.

Plant population per unit area was counted at 20 DAS and harvest. The maximum plant population (191.10) and (225.62) was recorded in BARI Gom-32 at 20 DAS and harvest, respectively. Whereas the minimum plant population (186.9) and (221.76) was reported in BARI Gom-30 at 20 DAS and harvest, respectively. By the influence of agronomic managements, the highest plant population (201.83) and (268.00) produced in M_7 at 20 DAS and harvest, respectively. While the lowest plant population (184.83) and (173.67) was found in M_2 and M_1 at 20 DAS and harvest, respectively. By the interaction effects of variety and agronomic managements, the highest plant population (207.33 and 269.33) was observed in V_2M_7 and V_1M_7 at 20 DAS and harvest, respectively. While the lowest plant population (180.33 and 176.67) was recorded in V_1M_2 and V_1M_1 at 20 DAS and harvest, respectively.

Plant height was measured at 20, 40, 80 DAS and harvest. At 20 and 40 DAS, both the variety showed more or less similar height but at 80 DAS and harvest, the higher plant height (64.47 cm) and (68.05 cm) was recorded in BARI Gom-30 whereas the lower (56.25 cm) and (59.49 cm) in BARI Gom-32, respectively. By the influence of agronomic managements, the tallest plant (21.65, 42.09, 68.42 and 71.98 cm) was found in M_7 while the shortest plant (15.92, 26.14, 46.67 and 48.96 cm) in M_1 at 20, 40, and 80 DAS and harvest, respectively. The interaction effects of variety and agronomic managements, showed the tallest plant height (22.53 and 43.32 cm) in V_2M_7 at 20 and 40 DAS and (71.40 and 76.01 cm) in V_1M_7 at 80 DAS and harvest, respectively. While the shortest plant (15.51 and 24.67 cm) was noticed in V_1M_1 at 20 and 40 DAS and (43.13 and 45.63 cm) was measured in V_2M_1 at 80 DAS and harvest, respectively.

Number of tillers linear meter^{-1} was counted at 20 DAS and harvest. The maximum tiller number (43.81) and (57.62) was recorded in BARI Gom-32 and BARI Gom-30 at 20 DAS and harvest, respectively. Whereas the minimum tiller number (36.05) and (55.57) was reported in BARI Gom-30 and BARI Gom-32, respectively. By the influence of agronomic managements, the highest number of tillers (50.67) and (70.83) produced in M_7 at 20 DAS and harvest, respectively. While the lowest number of tillers 31.67 and 40.33 was found in M_1 at 20 DAS and harvest, respectively. By the interaction effects of variety and agronomic managements, the highest tiller number (55.33 and 74.67) was observed in V_2M_7 and V_1M_7 at 20 DAS and harvest, respectively. While the lowest tiller number (30.00 and 38.67) was recorded in V_1M_1 at 20 DAS and harvest, respectively.

Number of leaves plant^{-1} was counted at 20, 40 and 80 DAS. At 20 DAS, both the variety showed more or less similar number of leaves. But at 40 and 80 DAS, the maximum leaves (9.48 and 11.71) were found in BARI Gom-30 while the minimum leaves (8.95 and 10.71) in BARI Gom-32. By the effects of agronomic managements, the highest number of leaves (6.83, 14.00 and 15.17) were observed in M_7 whereas the lowest (3.17, 6.33 and 7.33) in M_1 at 20, 40 and 80 DAS, respectively. By the interaction effects of variety and agronomic managements, the highest leaves (7.00 and 14.00) were found in V_2M_7 at 20 and 40 DAS, respectively. But at 80 DAS, the highest number of leaves (15.67) was recorded in V_1M_7. Whereas the lowest number leaves (3.00) were counted from V_1M_1 and at 40 and 80 DAS, the lowest leaves of 6.00 and 7.33 were reported in V_2M_1.

Length of leaf was measured at 20, 40 and 80 DAS. The higher length of leaf (12.83 cm) was recorded in BARI Gom-32 at 20 DAS, but at 40 and 80 DAS the higher length of leaf (14.63 cm and 14.25 cm) was recorded from BARI Gom-30, respectively. By the effects of agronomic managements, the longest leaf of 15.45 cm, 16.15 cm and 16.24 cm was obtained from M_7, while the shortest length of leaf 10.47 cm, 11.74 cm and 8.14 cm from M_1 treatment at 20, 40 and 80 DAS, respectively. By the interaction effects of variety and agronomic managements, the longest leaf (16.42 cm) was observed in V_2M_7 at 20 DAS, but at 40 and 80 DAS the longest leaf (16.54 cm) and (19.30 cm) was recorded in V_1M_7, respectively. Whereas the shortest leaf (10.34 cm) was found in V_1M_1 at 20 DAS, but at 40 and 80 DAS the shortest leaf (10.99 cm) and (6.53 cm) was obtained from V_2M_1, respectively.

At 20, 40 and 80 DAS, breadth of leaf was measured. At 20 DAS, BARI Gom-32 showed higher (0.46 cm) breadth of leaf but at 40 and 80 DAS, BARI Gom-30 showed higher breadth of leaf (0.72 cm) and (1.34 cm), respectively. While the lower breadth of leaf (0.43 cm) was measured in BARI Gom-30 at 20 DAS, but at 40 and 80 DAS the lower breadth of leaf (0.69 cm) and (1.17 cm) was recorded in BARI Gom-32, respectively. By the effects of agronomic managements, the maximum breadth of leaf (0.50, 0.84 and 1.46 cm) was recorded in M_7 whereas the minimum (0.39, 0.58 and 1.06 cm) in M_1 at different stages.

By the interaction effects of variety and agronomic managements, the maximum breadth of leaf (0.52 cm) was recorded in V_2M_1 at 20 DAS, but at 40 and 80 DAS the maximum breadth of leaf (0.87 cm) and (1.63 cm) was recorded from V_1M_7. Whereas the minimum breadth of leaf (0.39, 0.55 and 1.05 cm) was obtained from V_2M_1 at different stages.

Leaf area index was measured at 20, 40 and 80 DAS. The higher leaf area index (0.11) was recorded in BARI Gom-32 at 20 DAS, but at 40 and 80 DAS the higher leaf area index (0.39 and 1.20) was recorded from BARI Gom-30, respectively. By the effects of agronomic managements, the highest leaf area index 0.20, 0.85 and 2.10 was obtained from M_7, while the lowest leaf area index 0.03, 0.11 and 0.19 from M_1 treatment at 20, 40 and 80 DAS, respectively. By the interaction effects of variety and agronomic managements, the maximum leaf area index (0.24) was observed in V_2M_7 at 20 DAS, but at 40 and 80 DAS the maximum leaf area index (0.89) and (2.88) was recorded in V_1M_7, respectively. Whereas the minimum leaf area index (0.03) was found in V_1M_1 and V_2M_1 at 20 DAS, but at 40 and 80 DAS the minimum leaf area index (0.10) and (0.16) was obtained from V_2M_1, respectively.

Higher dry weight of plant (6.39 g) was weighed from BARI Gom-32 at 30 DAS but at 60 and 90 DAS, higher dry weight (32.29 g) and (71.91 g) was measured from BARI Gom-30; While the lower dry weight (5.86 g) from BARI Gom-30 at 30 DAS but at 60 and 90 DAS, (28.73 g) and (71.05 g) from BARI Gom-32. By the effects of agronomic managements, the maximum dry weight (8.53 g), (59.66 g) and (108.59 g) was recorded from M_7, while the minimum dry weight (3.53 g), (8.36 g) and (23.06 g) from M_1 at different stages. By the interaction effects of variety and agronomic managements, the maximum dry weight (8.55 g) was found in V_2M_7 at 30 DAS, but at 60 and 90 DAS (72.38 and 111.32 g) found in V_1M_7 and the minimum dry weight (3.56, 6.10 and 18.74 g) was found in V_1M_1 at different stages.

Higher SPAD value (48.46) and (52.09) was recorded in BARI Gom-32, while lower (44.69) and (49.37) in BARI Gom-30 at 40 and 70 DAS, respectively. By the effects of agronomic managements, the maximum SPAD value (51.52) and (54.66) was obtained from M_7, while the minimum (40.63) and (46.63) from M_1 at different growth stages. By the interaction effects of variety and agronomic managements, the maximum SPAD value (55.48) and (56.20) was found in V_2M_7, while the minimum SPAD value (40.07) and (46.34) in V_1M_1 at 40 and 70 DAS, respectively.

Longer flag leaf (14.82 cm) and pedicel length (13.30 cm) was measured in BARI Gom-30, while the shorter (9.81 cm) and (12.68 cm) in BARI Gom-32, respectively. By the effects of agronomic managements, the longest flag leaf (16.54 cm) and pedicel length (16.67 cm) was obtained from M_7, whereas the shortest (8.23 cm) and (8.19 cm) from M_1, respectively. By the interaction effects of variety and agronomic managements, the longest flag leaf (20.21 cm) and pedicel length (18.20 cm) was recorded from V_1M_7, while the shortest (7.71 cm) and (8.18 cm) from V_2M_1 and V_1M_1, respectively.

Higher maturity duration (81.58 days) was required in BARI Gom-32 and lower (80.91 days) in BARI Gom-30. By the effects of agronomic managements, the maximum maturity duration (107.17 days) was recorded in M_6 whereas the minimum (98.17 days) in M_4. Again, the highest maturity duration (108.67 days) was required in V_1M_3 while the lowest (98.00 days) in V_2M_4 by the interaction effects of variety and agronomic managements.

Higher dry weight of weed (13.90 g) was measured in BARI Gom-30 plot, while the lower (11.84 g) in BARI Gom-32 plot. By the effects of agronomic managements, the maximum dry weight of weed (43.05 g) was recorded in M_3 (no weeding), while the minimum (4.27 g) in M_1. By the interaction effects of variety and agronomic managements, the maximum weight (56.99 g) was obtained from V_1M_3 whereas the minimum (4.04 g) from V_1M_1.

Higher number of effective tillers linear meter^{-1} (55.81) was observed in BARI Gom-30 while the lower (54.38) in BARI Gom-32. By the effects of agronomic managements, the maximum effective tillers (74.00) were recorded in M_7 whereas the minimum (39.00) in M_1. Again, the maximum effective tillers (74.67) were found V_1M_7 while the minimum (37.33) in V_1M_1 by the interaction effects of variety and agronomic managements.

The longer spike (15.04 cm) was obtained from BARI Gom-30 while the shorter (12.26 cm) from BARI Gom-32. Again, the longest spike (15.22 cm) was recorded in M_7 while the shortest (10.87 cm) in M_1 by the effects of agronomic managements. By the interaction effects of variety and agronomic managements, the longest spike (16.53 cm) was found in V_1M_7 whereas the shortest (9.88 cm) in V_2M_1.

Higher spikelets number spike^{-1} (13.33) was counted from BARI Gom-30 whereas lower (11.48) from BARI Gom-32. By the effects of agronomic managements, the highest spikelets (15.17) were recorded from M_7 while the lowest (8.50) from M_1 by the effects of agronomic managements. Again, the maximum spikelets (16.33) were found in V_1M_7 whereas the minimum (8.33) in V_1M_1.

The higher number of grains spike^{-1} (32.57) was enumerated in BARI Gom-30 while lower (26.33) in BARI Gom-32. Again, the highest number of grains spike^{-1} (40.33) was counted in M_7 whereas the lowest (15.17) in M_1 by the effects of agronomic managements. By the interaction effects of variety and agronomic managements, the maximum number of grains (44.00) was recorded from V_1M_7 while the minimum (15.00) from V_1M_1.

Higher 1000-grain weight (45.14 g) was weighted in BARI Gom-30 and lower (45.12 g) in BARI Gom-32. By the effects of agronomic managements, the maximum 1000-grain weight (50.66 g) was noted from M_7 while the minimum (36.73 g) from M_1. Again, the highest 1000-grain weight (51.40 g) was obtained from V_1M_7 whereas the lowest (36.68 g) from V_2M_1 by the interaction effects of variety and agronomic managements.

Higher shelling percentage (81.58%) was found from BARI Gom-32 and lower (80.91%) from BARI Gom-30. Again, the maximum shelling percentage (83.53%) was obtained from M_7 while the minimum (76.08%) from M_1 by the effects of agronomic managements. By the interaction effects of variety and agronomic managements, the maximum shelling percentage (84.22%) was recorded in V_2M_7 where the minimum (75.85%) in V_2M_1.

The maximum grain yield (1.28 t ha^{-1}) was reported in BARI Gom-30 whereas the minimum (1.15 t ha^{-1}) in BARI Gom-32. By the effects of agronomic managements, the highest grain yield (1.78 t ha^{-1}) was found in M_7 while the lowest (0.39 t ha^{-1}) in M_1. Again, the highest grain yield (1.88 t ha^{-1}) was measured in V_1M_7 while the lowest (0.39 t ha^{-1}) in V_2M_1 by the interaction effects of variety and agronomic managements.

Higher straw yield (1.66 t ha^{-1}) was found in BARI Gom-30 while the lower (1.58 t ha^{-1}) in BARI Gom-32. Again, the maximum straw yield (2.14 t ha^{-1}) was recorded in M_7 whereas the minimum (0.77 t ha^{-1}) in M_1 by the effects of agronomic managements. By the interaction effects of variety and agronomic managements, the maximum straw yield (2.22 t ha^{-1}) was reported in V_1M_7 while the minimum (0.76 t ha^{-1}) in V_1M_1.

Maximum biological yield (2.94 t ha^{-1}) was recorded in BARI Gom-30 while the minimum (2.74 t ha^{-1}) in BARI Gom-32. By the effects of agronomic managements, the highest biological yield (3.92 t ha^{-1}) was found in M_7 whereas the lowest (1.16 t ha^{-1}) in M_1. Again, the highest biological yield (4.10 t ha^{-1}) was obtained from V_1M_7 while the lowest (1.16 t ha^{-1}) from V_1M_1 by the interaction effects of variety and agronomic managements.

The higher harvest index (42.14%) was recorded in BARI Gom-30 and lower (40.78%) in BARI Gom-32. By the effects of agronomic managements, the maximum harvest index (45.40%) was found in M_7 while the minimum (33.74%) in M_1. Again, the highest harvest index (45.87%) was obtained from V_1M_7 whereas the lowest (33.37%) from V_2M_1 by the interaction effects of variety and agronomic managements.

Considering the findings of the present experiment, following conclusions may be drawn:

- ✓ The variety BARI Gom-30 and BARI Gom-32 showed similar grain yield.
- ✓ The complete agronomic management showed maximum growth and yield of wheat. No management reduced 78% yield of wheat that followed by no irrigation (70%), no fertilizer (33%), no weeding (19%), no thinning (14%) and no pesticide (10%) application compared to complete management.
- ✓ BARI Gom-30 with complete agronomic managements performed better compared to the BARI Gom-32 and irrespective of agronomic managements, the yield reduction was higher in BARI Gom-30.
- ✓ Irrigation considered as the most important yield limiting factor of wheat that followed by fertilizer.

Considering the facts of the present experiment, further studies in the following areas may be suggested:

- ✓ Similar studies need to be conducted in different Agro-Ecological Zones (AEZ) of Bangladesh.
- ✓ More experiments may be carried out with other varieties and agronomic managements.

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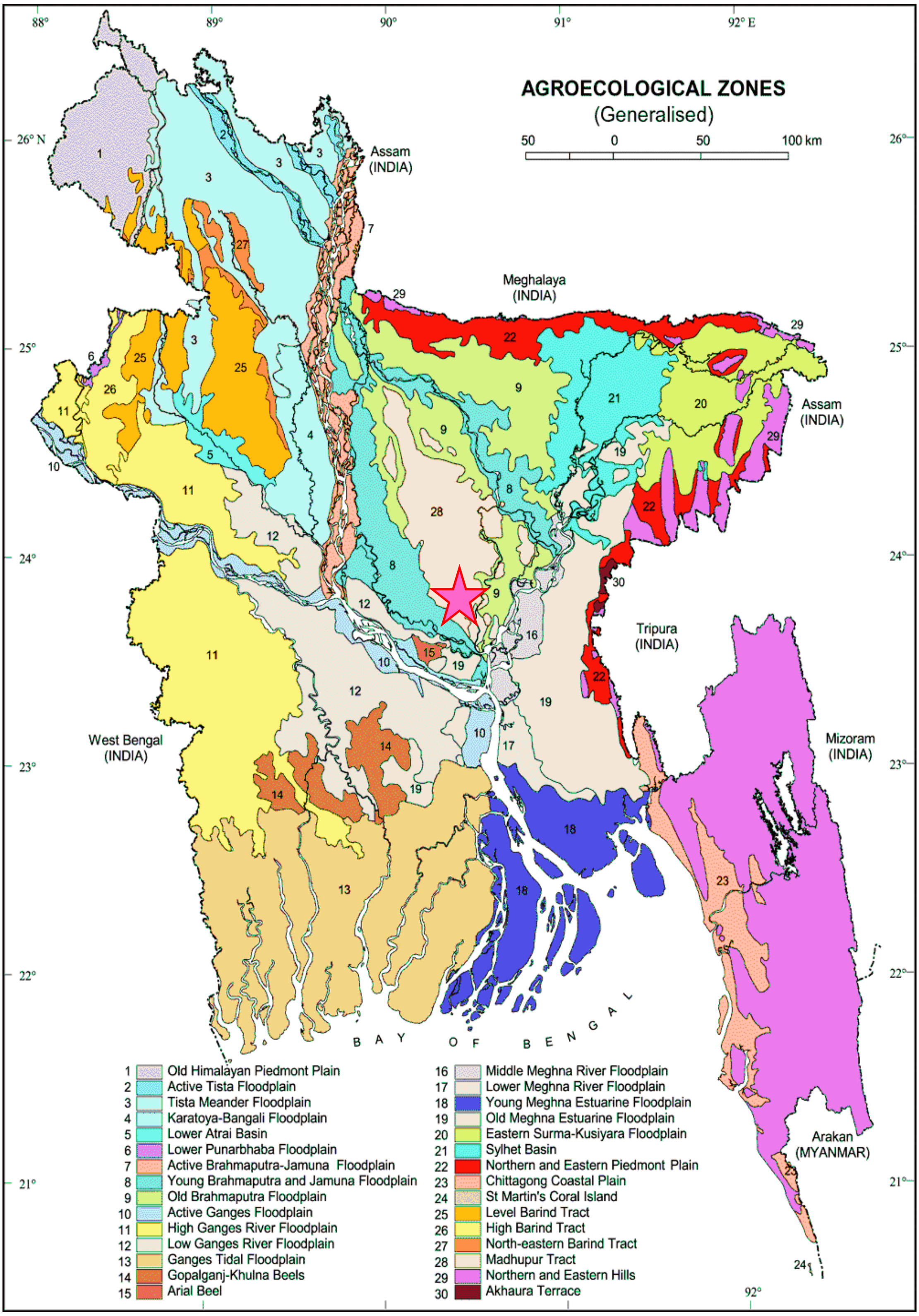
APPENDICES

Appendix I. Map showing the experimental site under study



★ Shows the experimental site

Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological properties of the soil

Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical properties of the soil

Particle size analysis	Results
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Color	Dark grey
Consistency	Grounder

Source: Soil Resources Development Institute (SRDI), Dhaka.

Appendix III. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2018 to February 2019

Year	Month	Air temperature (° C)			Relative humidity (%)	Total Rainfall (mm)
		Minimum	Maximum	Mean		
2018	November	19.2	29.6	24.40	53	34.4
2018	December	14.1	26.4	20.25	50	12.8
2019	January	12.7	25.4	19.05	46	7.7
2019	February	15.5	28.1	21.80	37	28.9

* Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka-1212

Appendix IV. Mean square values of plant population at different growth stages of wheat

Source of variation	Degrees of freedom	Plant population at	
		20 DAS	Harvest
Replication	2	639.21	442.17
Variety (A)	1	886.88^{NS}	156.21^{NS}
Error I	2	125.31	79.93
Agronomic managements (B)	6	171.33**	6842.97**
Interaction (A×B)	6	25.16*	139.16*
Error II	24	18.07	75.41

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix V. Mean square values of plant height at different growth stages of wheat

Source of variation	Degrees of freedom	Plant height at			
		20 DAS	40 DAS	80 DAS	Harvest
Replication	2	1.99	14.15	15.63	29.48
Variety (A)	1	21.95^{NS}	49.86^{NS}	709.88*	770.40*
Error I	2	2.68	2.85	11.68	16.95
Agronomic managements (B)	6	21.87**	185.86**	388.19**	435.98**
Interaction (A×B)	6	0.98*	0.67*	13.16**	16.68**
Error II	24	11.54	2.62	1.46	1.54

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix VI. Mean square values of tiller number at different growth stages of wheat

Source of variation	Degrees of freedom	Tiller number linear m^{-1} at	
		20 DAS	Harvest
Replication	2	3.43	78.95
Variety (A)	1	632.60*	44.02^{NS}
Error I	2	16.10	2.95
Agronomic managements (B)	6	273.94**	686.27**
Interaction (A×B)	6	14.98*	38.08**
Error II	24	4.98	2.76

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix VII. Mean square values of leaf number at different growth stages of wheat

Source of variation	Degrees of freedom	Number of leaves plant^{-1} at		
		20 DAS	40 DAS	80 DAS
Replication	2	0.024	2.78	15.50
Variety (A)	1	0.214^{NS}	2.88^{NS}	10.50*
Error I	2	0.071	0.74	0.50
Agronomic managements (B)	6	9.651**	44.93**	44.21**
Interaction (A×B)	6	0.048*	0.44*	1.00*
Error II	24	0.075	0.46	3.31

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix VIII. Mean square values of length of leaf at different growth stages of wheat

Source of variation	Degrees of freedom	Length of leaf at		
		20 DAS	40 DAS	80 DAS
Replication	2	0.27	1.34	1.53
Variety (A)	1	2.90^{NS}	29.45*	178.31**
Error I	2	0.53	0.34	0.09
Agronomic managements (B)	6	15.97**	14.22**	49.30**
Interaction (A×B)	6	1.17**	0.37*	2.79*
Error II	24	0.30	0.67	0.77

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix IX. Mean square values of breadth of leaf at different growth stages of wheat

Source of variation	Degrees of freedom	Breadth of leaf at		
		20 DAS	40 DAS	80 DAS
Replication	2	0.00005	0.00066	0.00832
Variety (A)	1	0.01449*	0.00720^{NS}	0.29167*
Error I	2	0.00035	0.00062	0.00167
Agronomic managements (B)	6	0.01032**	0.04521**	0.11165**
Interaction (A×B)	6	0.00090**	0.00179*	0.01788*
Error II	24	0.00012	0.00096	0.00525

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix X. Mean square values of leaf area index at different growth stages of wheat

Source of variation	Degrees of freedom	Leaf area index (LAI) at		
		20 DAS	40 DAS	80 DAS
Replication	2	0.00008	0.01974	0.30578
Variety (A)	1	0.01545*	0.02254*	3.45736**
Error I	2	0.00025	0.00072	0.01429
Agronomic managements (B)	6	0.02011**	0.39206**	2.76551**
Interaction (A×B)	6	0.00137**	0.00083*	0.42557**
Error II	24	0.00008	0.00171	0.02470

*: Significant at 5% level of probability; **: Significant at 1% level of probability

Appendix XI. Mean square values of dry weight of plant at different growth stages of wheat

Source of variation	Degrees of freedom	Dry weight of plant at		
		30 DAS	60 DAS	90 DAS
Replication	2	0.03	35.40	371.73
Variety (A)	1	3.05*	133.14*	7.77^{NS}
Error I	2	0.15	7.17	12.36
Agronomic managements (B)	6	15.86**	1772.15**	5075.66**
Interaction (A×B)	6	0.75**	172.17**	79.92*
Error II	24	0.09	19.49	37.38

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XII. Mean square values of SPAD values at different growth stages of wheat

Source of variation	Degrees of freedom	SPAD values at	
		40 DAS	70 DAS
Replication	2	1.46	0.26
Variety (A)	1	148.52^{NS}	77.90**
Error I	2	8.28	0.03
Agronomic managements (B)	6	73.27**	50.13**
Interaction (A×B)	6	6.04*	3.43**
Error II	24	3.12	0.29

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XIII. Mean square values of flag leaf length, pedicel length and maturity duration of wheat

Source of variation	Degrees of freedom	Length of flag leaf	Length of pedicel	Maturity duration
Replication	2	6.27	1.72	37.310
Variety (A)	1	263.20**	4.06^{NS}	72.024*
Error I	2	1.01	2.21	1.595
Agronomic managements (B)	6	52.67**	46.73**	87.937**
Interaction (A×B)	6	7.75**	3.89*	8.968*
Error II	24	1.22	2.09	4.869

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XIV. Mean square values of dry weight of weed from different treatment's plots

Source of variation	Degrees of freedom	Dry weight of weed
Replication	2	5.92
Variety (A)	1	44.25*
Error I	2	2.13
Agronomic managements (B)	6	1097.81**
Interaction (A×B)	6	196.98**
Error II	24	7.51

*: Significant at 5% level of probability; **: Significant at 1% level of probability

Appendix XV. Mean square values of effective tillers number m^{-1} and spike length of wheat

Source of variation	Degrees of freedom	No. of effective tillers m^{-1}	Length of spike
Replication	2	9.24	0.45
Variety (A)	1	21.43^{NS}	81.34**
Error I	2	22.57	0.03
Agronomic managements (B)	6	985.49**	14.58**
Interaction (A×B)	6	31.21*	0.41*
Error II	24	35.68	0.38

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XVI. Mean square values of spikelets number spike^{-1} and grains number spike^{-1} of wheat

Source of variation	Degrees of freedom	Number of spikelets spike^{-1}	Number of grains spike^{-1}
Replication	2	0.17	4.95
Variety (A)	1	36.21**	408.60**
Error I	2	0.21	1.81
Agronomic managements (B)	6	34.55**	469.65**
Interaction (A×B)	6	3.55**	13.76**
Error II	24	0.44	2.33

*: Significant at 5% level of probability; **: Significant at 1% level of probability

Appendix XVII. Mean square values of 1000-grain weight and shelling percentage of wheat

Source of variation	Degrees of freedom	1000-grain weight	Shelling percentage
Replication	2	0.616	3.694
Variety (A)	1	0.004^{NS}	4.759^{NS}
Error I	2	0.358	1.330
Agronomic managements (B)	6	151.041**	58.685**
Interaction (A×B)	6	2.291*	2.042*
Error II	24	1.029	2.783

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XVIII. Mean square values of grain yield and straw yield of wheat

Source of variation	Degrees of freedom	Grain yield	Straw yield
Replication	2	0.00114	0.00071
Variety (A)	1	0.15683^{NS}	0.06451^{NS}
Error I	2	0.01276	0.02323
Agronomic managements (B)	6	1.75928**	1.90420**
Interaction (A×B)	6	0.02338**	0.01046*
Error II	24	0.00257	0.00549

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

Appendix XIX. Mean square values of biological yield and harvest index of wheat

Source of variation	Degrees of freedom	Biological yield	Harvest index
Replication	2	0.00347	0.358
Variety (A)	1	0.42252^{NS}	19.465*
Error I	2	0.06996	0.291
Agronomic managements (B)	6	7.31367**	105.258**
Interaction (A×B)	6	0.06249*	3.427*
Error II	24	0.01173	1.589

*: Significant at 5% level of probability; **: Significant at 1% level of probability; NS: Non significant

LIST OF PLATES

Plate 1. Field view after sowing of seed

Plate 2. Field view after emergence of seedlings

Plate 3. Field view after completing tagging & drainage channel

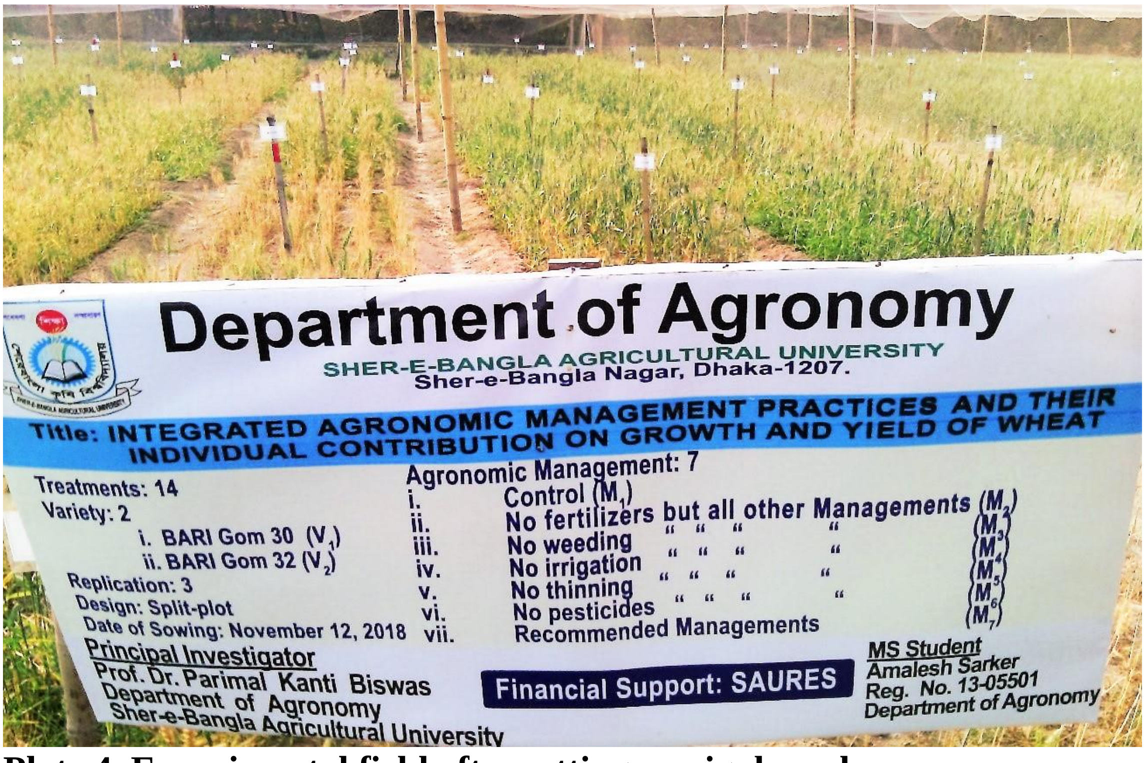


Plate 4. Experimental field after setting up signboard

Plate 5. Experiment field during maturity stage

Plate 6. Sun-drying of grain after threshing and winnowing