INFLUENCE OF COWDUNG TO WATER STRESS MANAGEMENT IN WHEAT

MD. SHAHIN REZA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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MD. SHAHIN REZA

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Approved by:

Prof. Dr. A. K. M. Ruhul Amin **Supervisor**	**Prof. Dr. Mirza Hasanuzzaman** **Co-supervisor**

Prof. Dr. Tuhin Suvra Roy
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar
Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF COWDUNG TO WATER STRESS MANAGEMENT IN WHEAT**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. SHAHIN REZA**, Registration no. **18-09301** 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.

Date:
Place: Dhaka, Bangladesh

Prof. Dr. A. K. M. Ruhul Amin
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University,
Dhaka-1207

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The Author
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ABSTRACT

An experiment was conducted in the net house of the Agronomy department, Sher-e-Bangla Agricultural University, Dhaka 1207 during the period from November 2018 to March 2019 to select the optimum dose of cow dung to manage water stress in wheat. The experiment was comprised of three factors *viz.* factor A: Variety- 2; i) V_1 = BARI Gom-28, ii) V_2 = BARI Gom-30; factor B: Cow dung doses- 5, i) C_0 = Recommended dose of chemical fertilizers (RDCF) + Control (Without cow dung), ii) C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + Recommended dose of cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose; factor C: Water stress imposition by avoiding irrigation- 4; i) D_0 = Control (without Water stress), i) D_1 = Crown root initiation stage, ii) D_2 = Booting stage, iii) D_3 = Anthesis stage. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data were collected on different aspects of yield attributes and yield of wheat. Results revealed that BARI Gom-30 gave the highest grain yield (5.73 g plant^{-1}). This may be attributed to the highest number of effective tillers plant^{-1} (4.76), spike length (10.56 cm), spikelets spike^{-1} (15.01) and 1000-grains weight (46.67 g) in this variety. Considering cow dung application, C_4 (RDCF + 50% higher cow dung of recommended dose) was the highest grain yielder (5.72 g plant^{-1}) than other doses which may perhaps the highest effective tillers plant^{-1} (5.60), spike length (10.82 cm), spikelet spike^{-1} (15.80), grains spikelet^{-1} (1.98), grains spike^{-1} (30.92) and 1000-grains weight (49.19 g) in this treatment. In respect of Water stress imposition treatments, grain yield was found the highest in control treatment (without imposition of Water stress stress) and that of second highest was recorded in Water stress imposition at booting stage treatment (D_2). Regarding the interaction of variety, cow dung and Water stress imposition, the interaction of BARI Gom-30 × RDCF + 50% higher cow dung of recommended dose × without Water stress imposition ($V_2C_4D_0$) was the highest yielder among the other interactions which was attributed to higher effective tillers plant^{-1}, spike length, spikelet spike^{-1} and 1000-grains weight, but interaction of $V_2C_4D_2$ may be suggested in case of water limited situation; as this interaction showed statistically similar and higher yield with $V_2C_4D_0$ interactions.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
eds.	editors
et al.	et alia (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	variety
viz.	namely

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the predominant cereal crops in the world under the Poaceae family and the main sources of carbohydrate and contains a considerable amount of protein, minerals and vitamins. It occupies global rank one in aspect of worldwide production and consumption. It is an important cereal crop of tropical and subtropical regions of the world. It is the third important cereal crop next to maize in Bangladesh (Al-Musa *et al.*, 2012). The area under wheat cultivation during 2018–2019 was about 3,30,348 hectares producing 10,16,811 metric tons of wheat with an average yield of 3.078 t ha^{-1} which was 1.66 % lower than the year 2017–18 (BBS, 2020).

On a worldwide scale, wheat contributes approximately 30% of total cereal production (Lobell and Gourdji, 2012). The wheat yield of Bangladesh is much lower comparing to other wheat producing countries in the world due to the fact of growing wheat under rainfed condition (Bazzaz, 2013), which are very low in Bangladesh compared to the average yield of Ireland, Netherlands, Belgium and United Kingdom recorded 9.38, 9.37, 9.33 and 8.93 t ha^{-1}, respectively (FAO, 2019). Moreover, there can be a range of reasons for low yield of wheat including inadequate knowledge, lack of high yielding varieties, lack of good quality seed, untimely seeding, low fertilization, irrigation scheduling, seed rate and inadequate extension efforts etc. The main reason for the declining in wheat area is the prevailing temperature during the grain filling period. If low temperatures are prolonged in the winter season, the yield of wheat is increased. If winter is short, the yield declines due to the temperature sensitivity of this crop. The wheat crop is sensitive to heat and also water stresses mainly at the flowering and grain development stages, which negatively affect the yield and grain quality (lower weight of 1000-grains and change in protein quality). Annual production variability estimated at ~40% was mainly due to heat waves and drought situations in major wheat producing belts throughout the world (Zampieri *et al.*, 2017). Although an increase in temperature is beneficial for crop productivity in some cooler regions of the world, drought still significantly reduces national cereal production by 9–10% on a global scale via negative effects on plant growth, physiology, and grain development (Farooq *et al.*, 2014). Caused by reduced precipitation and increased temperature, drought has been the most important limiting factor for crop productivity and, ultimately, for food security worldwide (Daryanto *et al*., 2017).

Water stress is one of the major abiotic stresses, which adversely affects crop growth and yield. Drought is the most common environmental stress affecting about 32% of the 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries (Rajaram, 2000). Water stress reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, transpiration, translocation, and ion uptake, carbohydrate nutrient metabolism and growth promoters. It affects both elongation and expansion growth, which ultimately affects the yield of plants (Farooq *et al*., 2009). Understanding of plant responses to water stress is of great importance and a fundamental part for making the crops tolerant to stress conditions (Zhao *et al*., 2008). Water stress affect crops at all growth stages which affects grain yield and yield components. Water stress induced at stem elongation stage, flowering and grain filling stages reduced 32%, 32% and 35% of grain yield, respectively (Mirzaei *et al*., 2011).

The organic matter content as well as the fertility status of Bangladesh soil is decreasing day-by-day (BARC, 2012). This depletion has arisen mainly due to continuous mining of soil nutrient over decades without adequate replenishment. Now, it is well agreed that depleted soil fertility is a major constraint for higher crop production in Bangladesh and indeed, the yield of several crops is declining in some soils. Maintenance of soil fertility is a prerequisite for long-term sustainable agriculture and organic manure can play a vital role in sustaining soil fertility and crop production. Incorporation of soil amendments (cow dung, vermicompost, compost, biochar, poultry litter etc.) enhanced soil water holding capacity, soil water permeability, saturated hydraulic conductivity (SHC), reduced soil strength, modification in soil bulk density and modified aggregate stability (Peng *et al*., 2011). Soil amendments increases adsorption properties allowing a greater retention of water and nutrients in the soil solution. The ability to retain a relatively large quantity of water aids plant growth when under water stress. The grain yield and yield components of wheat significantly increased with the application of different organic materials (Sarwar *et al*., 2008). Irrigating the crop at 60% water holding capacity and applying mineral nitrogen 60 kg fed^{-1}, with presence of the chicken manure as an organic fertilizer produced the highest wheat yield through two growth seasons (Yassen *et al*., 2006). Cow dung and vermicompost can play an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and drought prone soils.

Considering the above facts, the present study was undertaken with the following objectives:

1. To confirm the effect of cow dung to mitigate water stress in wheat, and

2. To select a suitable dose of cow dung to mitigate water stress in wheat.

CHAPTER II

REVIEW OF LITERATURE

The growth and yield of wheat are very closely related to the availability of water at different growth stages. Time of water supply or irrigation frequencies at different growth stages is a crucial factor for successful wheat production. Water scarcity or drought hamper wheat production in many ways. There might be differences in different cultivars response to the water stress. Fertilizer, especially from organic sources can have a great impact on successful wheat cultivation. A number of mitigation approaches have been tried to control drought in wheat. Limited research works are available on mitigation of drought in wheat in Bangladesh. The review includes reports of several investigators which appear pertinent in understanding the problem and which may lead to the explanation and interpretation of results of the present investigation. Some of the relevant findings of the research on impact of cow dung on reduction of drought in wheat are reviewed in this chapter.

2.1 Effect of variety on plant growth parameters of wheat

Alam (2013) conducted an experiment to study growth and yield potentials of wheat as affected by agronomic practices. The experiment consisted of three factors such as (a) two methods of planting *viz.* conventional and bed planting (b) four wheat varieties namely Protiva, Sourav, Shatabdi and Prodip and (c) four levels of nitrogen viz. 0, 60, 110 and 160 kg N ha^{-1}. The overall results indicated that Prodip showed better performance in bed planting system with 160 Kg N ha^{-1}. Prodip produced the highest total dry matter up to grain filling stage with the application of 160 kg N ha^{-1}.

Naher (2013) conducted an experiment to find out the effect of variety, sowing time and irrigation on growth of wheat. The experiment comprised of three factors: Factors A: four improved wheat varieties, *viz.* (i) BARI Gom 21

(Shatabdi), (ii) BARI Gom 25, (iii) BARI Gom 26 and (iv) BARI Gom 27; Factor B: three sowing times, *viz.* (a) Sowing at 18 November, (b) Sowing at 03 December and (c) Sowing at 19 December; Factor C: two irrigation, *viz.* (a) Irrigation; (b) No irrigation, i.e. control. Experimental results indicated that plant height increased up to 45 DAS and there after declined. Variety, sowing time, irrigation and their interactions had significant effect on the morphological parameters except CGR and RGR. At maturity, the treatment combination of BARI Gom 21 (Shatabdi) sown at 18 November with irrigation showed significantly the highest plant height (98.95 cm), highest number of leaves plant^{-1} (39.89), highest dry matter weight plant^{-1} (19.24 g) and the highest number of tillers plant^{-1} (7.58).

Al-Musa *et al.* (2012) set up a pot experiment to study the performance of some BARI released wheat varieties in coastal region. Four wheat varieties *viz.* BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were planted in the field to evaluate their comparative performance in respect of germination percentage, growth, yield attributing characters and yield. Among the four varieties, BARI Gom-26 showed superior performance irrespective of all parameters studied. The taller plant (47.91 cm), the maximum number of effective tillers plant^{-1} (18.08) and the maximum total dry matter content (TDM) (17.37 g plant^{-1}) was obtained with BARI Gom-26.

Hussain *et al.* (2012) evaluated phenology, growth and yield of three elite varieties of wheat (Gourab, BARI Gom-25 and BARI Gom-26) under two sowing conditions: optimum (sown on November 15) and late heat stress condition (sown on December 27). All wheat varieties, when sown late, faced severe temperature stress that significantly affected phenology, growth and finally yield. Taking into consideration dry matter (fresh and dry weight) partitioning, BARI Gom-26 performed better both in optimum and late heat stress, followed by BARI Gom-25 while Gourab performed the worst.

Mushtaq *et al.* (2011) carried out an experiment where two wheat genotypes *viz.* a) Mairaj-2008 and b) Fareed-2006 were used to evaluate the effect of drought induced conditions at different crop growth stages according to the given irrigation schedules, i.e. (i): Control (no drought), (ii): Irrigation skip at tillering (20–40 DAS), (iii): Irrigation skip at jointing (40–75 DAS), iv: Irrigation skip at spike emergence (75–90 DAS) and v: Irrigation skip at grain formation (105–115 DAS). It was recorded that Mairaj-2008 produced significantly taller plant and higher number of productive tillers per plant than that of Fareed-2006.

Ahamed *et al.* (2010) observed the effect of high temperature stress on the leaf growth and dry matter partitioning of 5 wheat varieties (Sourav, Pradip, Sufi, Shatabdi and Bijoy) from a field experiment which was conducted with normal sowing (sowing at November 30) and late sowing (sowing at December 30). Leaf number of Pradip (5.37) and Shatabdi (5.01) was the highest in the normal and late sowing condition, respectively and it was lowest in the variety Bijoy (4.87) followed by Sufi (3.62) under the normal and late sowing condition. Both under normal and late sown heat stressed condition the variety Shatabdi showed the highest leaf area, longest leaf sheath and lamina. It was observed that stem dry weight was the highest in Shatabdi under both normal (2.267 g) and heat stressed (1.801 g) environment and Pradip (1.202 g) and Sufi (1.166 g) produced the lowest stem dry weight in those conditions. Both under normal and late sown heat stressed condition, the variety Shatabdi showed the concomitant increase of dry matter (5.976 g and 4.459 g tiller^{-1} under normal and heat stress, respectively). However, the spike dry weight was the maximum in Bijoy and the minimum was in Sourav and Sufi regardless of the growing condition.

Mehmet and Telat (2006) conducted field trials in two locations over two years to observe the adaptation and stability statistics of 20 bread wheat genotypes for yield performances. All the genotypes showed stability for their traits of plant density and days to heading. There were differences in stability performances among the genotypes for the trait of plant height. The instability for plant height among the genotypes were originated from the mean squares of deviation from regression.

2.2 Effect of variety on yield contributing parameters of wheat

Al-Musa *et al.* (2012) conducted a pot experiment to study the performance of some BARI released wheat varieties in coastal region. Four wheat varieties *viz.* BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were planted in the field to evaluate their comparative performance in respect of germination percentage, growth, yield attributing characters and yield. Among the four varieties, BARI Gom-26 showed superior performance irrespective of all parameters studied. BARI Gom-26 was the most effective to produce the maximum number of grains spike^{-1} (38.52) and higher weight of 1000-grains (49.38 g).

Mushtaq *et al.* (2011) carried out an experiment where two wheat genotypes *viz.* a) Mairaj-2008 and b) Fareed-2006 were used to evaluate the effect of drought introduced conditions at different crop growth stages according to the given irrigation schedules, i.e. (i): Control (no drought), (ii): Irrigation skip at tillering (20–40 DAS), (iii): Irrigation skip at jointing (40–75 DAS), iv: Irrigation skip at spike emergence (75–90 DAS) and v: Irrigation skip at grain formation (105–115 DAS). It was recorded that Mairaj-2008 produced significantly higher number of spikelets spike^{-1} and longer spike than that of Fareed-2006.

Ahamed *et al.* (2010) observed the effect of high temperature stress on the leaf growth and dry matter partitioning of 5 wheat varieties (Sourav, Pradip, Sufi, Shatabdi and Bijoy) from a field experiment which was conducted with normal sowing (sowing at November 30) and late sowing (sowing at December 30). Weight of 1000-grains of variety Bijoy (34.94 g) and Shatabdi (33.30 g) were higher in late sowing, whereas Sufi had the lowest weight of 1000-grains (23.81 g).

Alam *et al.* (2008) carried out a research work with twenty wheat varieties / lines to study the effect of source-sink manipulation on grain yield in wheat. Significant variations among the genotypes were observed for number of grains spike^{-1}. Removal of flag leaf caused decrease in number of grains spike^{-1} by 9.94%. Similarly, removal of all leaves caused reduction of number of grains spike by 17.17%. On the other hand, removal of 50% spikelet decreased 41.03% in number of grains spike^{-1}. Similarly, 25% spikelets removal reduced number of grains spike^{-1} by 25.13%. The variety / lines BL-1020, Ananda and Akbar showed higher decrease in number of grains spikes^{-1} and weight of 100-grains due to defoliation treatment.

Mehmet and Telat (2006) set up field trials in two locations over two years to observe the adaptation and stability statistics of 20 bread wheat genotypes for yield performances. There were differences in stability performances among the genotypes for the trait of number of grains spike^{-1}. The instability for number of grains spike^{-1} was resulted from not only the mean squares of deviation from regression but also from the differences among regression coefficients of genotypes. There were differences in stability performances among the genotypes for the trait of weight of 1000-grains. The instability for the trait of weight of 1000-grains was resulted from not only the mean squares of deviation from regression but also from the differences among regression coefficients of genotypes.

Sikder *et al.* (2001) conducted an experiment with ten recommended wheat (*Triticum aestivum* L.) varieties with two sowing conditions i.e. optimum sowing (November 30) and late sowing (December 30). The experiment was conducted to determine the relative heat tolerance of the wheat varieties and to evaluate the relative yield performance of heat tolerant and heat sensitive wheat varieties under late-grained conditions. Based on membrane thermo-stability (MT) test, four varieties (Ananda, Pavon, Aghrani, and Barkat) took maximum heat killing time and were classified as relative heat tolerant, three varieties (Akbar, Kanchan and Protiva) as moderately tolerant and the rest three varieties (Balaka, Sawgat and Sonora) took the shortest heat killing time and considered as heat sensitive. The relative spike number per plant was found to be ranged from low-to-high in heat tolerant and moderately tolerant varieties. In heat sensitive varieties, the relative spike number per plant was moderate to high. The number of grains spike^{-1} of tolerant and moderately tolerant varieties showed higher relative performance compared to sensitive varieties, but the relative spike number per plant was found to range from low-to-high in heat tolerant and moderately tolerant varieties. In heat sensitive varieties, the relative spike number per plant was moderate to high. Thus, the results suggested that in addition to membrane thermo-stability test, the high relative grain number per spike could be used to determine the heat tolerance of wheat varieties under late-grained warmer conditions. The weight of 1000-grains of tolerant and moderately tolerant varieties showed higher relative performance compared to sensitive varieties. The results suggested that in addition to membrane thermo-stability test, the high weight of 1000-grains could be used to determine the heat tolerance of wheat varieties under late-grained warmer conditions.

Arabinda *et al.* (1994) from their experiment naming ‘Influence of sowing time on the performance of different wheat genotypes’ observed that the genotype CB-15 produced higher number of spikes m^{-2} and higher number of grains spike^{-1}.

Jahiruddin and Hossain (1994) from their experiment on wheat varieties observed that weight of 1000-grains varied among the three varieties namely Sonalika, Kanchan and Aghrani.

2.3 Effect of variety on yield of wheat

Alam (2013) conducted an experiment to study growth and yield potentials of wheat as affected by agronomic practices. The experiment consisted of three factors: (a) two methods of planting *viz.* conventional and bed planting (b) four wheat varieties namely Protiva, Sourav, Shatabdi and Prodip and (c) four levels of nitrogen *viz.* 0, 60, 110 and 160 kg N ha^{-1}. The overall results indicated that Prodip showed better performance in bed planting system with 160 Kg N ha^{-1}. Prodip produced the maximum grain yield with the application of 160 kg N ha^{-1}.

Rahman *et al.* (2013) carried out a field trial to examine the response of seven wheat varieties at two levels of lime. The wheat varieties used in this study were Shatabdi, Sufi, Sourav, Bijoy, Prodip, BARI Gom-25 and BARI Gom-26. There were variations in lime response among the wheat varieties. The index of relative adaptability (IRA %) for yield of BARI Gom-26 and Bijoy was more than 100% for both the years. The results indicated that these two wheat varieties are relatively tolerant to low pH and could be adapted in acidic soil.

Al-Musa *et al.* (2012) set up a pot experiment to study the performance of some BARI released wheat varieties in coastal region. Four wheat varieties *viz.* BARI Gom-23, BARI Gom-24, BARI Gom-25 and BARI Gom-26 were planted in the field to evaluate their comparative performance in respect of germination percentage, growth, yield attributing characters and yield. Among the four varieties, BARI Gom-26 showed superior performance irrespective of all parameters studied except yield reduction percentage. Among the BARI varieties, BARI Gom-26 produced greater germination (61.00%) at 13 days judged against other varieties. BARI Gom-26 was the most effective variety to produce the higher grain yield (3.35 t ha^{-1}), maximum straw yield (8.50 g $plant^{-1}$) and greater harvest index (4.03%).

Hussain *et al.* (2012) evaluated phenology, growth and yield of three elite varieties of wheat (Gourab, BARI Gom-25 and BARI Gom-26) under two sowing conditions: optimum (sown on November 15) and late heat stress condition (sown on December 27). All wheat varieties, when sown late, faced severe temperature stress that significantly affected phenology, growth and finally yield. Taking into consideration grain yield, BARI Gom-26 performed better both in optimum and late heat stress, followed by BARI Gom-25 while Gourab performed the worst. Based on heat tolerance parameters [Relative

Performance (RP) and Heat Susceptibility Index (HSI)], BARI Gom-25 (RP: 79%; HIS: 0.7) was the best performing variety followed by BARI Gom-26 (RP: 74%; HIS: 0.9) under heat stress while Gourab (RP: 61%; HIS: 1.3) was sensitive to heat.

Khakwani *et al.* (2012) conducted an experiment on 6 bread wheat varieties (Damani, Hashim-8, Gomal-8, DN-73, Zam-04 and Dera-98) which were subjected to 2 treatments i.e., control treatment (100% field capacity) and stressed treatment (20 days water stress was given during booting stage and 20 days water stress after anthesis). The findings revealed highly significant differences among means of wheat varieties in both physiological and yield traits. Almost all varieties showed their best adaptation under stressed environment. However, Hashim-8 and Zam-04 behaved exclusively and indicated higher relative water content (RWC), mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) whereas stress susceptibility index (SSI) and tolerance (TOL) estimated at its lowest, as these traits are recognized beneficial drought tolerance indicators for selection of a stress tolerant variety. Similarly, total grain yield per plant, total biological yield per plant and harvest index was also higher in the same wheat varieties that put them as good candidates for selection criteria in wheat breeding program for drought resistant.

Abdelmulaa (2011) evaluating the result of an experiment in consecutive two years concluded that the induced terminal heat stress during both years was severe enough to cause a reduction in yield of the tested genotypes. The genetic material used in this study composed of 15 genotypes of bread wheat (*Triticum aestivum* L.), eleven of them were locally developed advanced breeding lines and four were commercial released varieties, used as checks. The heat stress was simulated by using three dates of sowing: S_1, S_2 and S_3, with interval of 15 days. In the first season (2005/06), the sowing dates, S_1, S_2 and S_3 were on the 13th of November, 28th of November and 12th of December, respectively. While in the second season (2006/07), they were on the 15th of November, 30th of November, and 14th of December, respectively. The first sowing date (S_1) was considered as non-stress environment (NSE) and the last two were considered as heat stress environments (HS_2E and HS_3E), with terminal heat stress. The determined differential genotypic variability to terminal heat stress and the estimated correlation between yield and its components could be exploited in breeding programs to identify and develop new heat tolerant widely adapted cultivars. Such cultivars could be suitable for optimum sowing date as well as for terminal heat stress, for example, genotype OASIS / KAUZ // 3*BCN. Moreover, the genotype KAUZ"S"657C_1-3-6-2-2-1-2 which exhibited a specific adaption and high yielding only under late sowing, could be identified and selected for improving tolerance to terminal heat stress.

Mushtaq *et al.* (2011) carried out an experiment where two wheat genotypes *viz.* a) Mairaj-2008 and b) Fareed-2006 were used to evaluate the effect of drought introduced conditions at different crop growth stages according to the given irrigation schedules, i.e. (i): Control (no drought), (ii): Irrigation skip at tillering (20–40 DAS), (iii): Irrigation skip at jointing (40–75 DAS), iv: Irrigation skip at spike emergence (75–90 DAS) and v: Irrigation skip at grain formation (105–115 DAS). It was recorded that Mairaj-2008 produced significantly higher grain yield, higher biological yield and harvest index than that of Fareed-2006. Both of the wheat varieties have no genetic potential to withstand against drought.

Ahamed *et al.* (2010) observed the effect of high temperature stress on the leaf growth and dry matter partitioning of 5 wheat varieties (Sourav, Pradip, Sufi, Shatabdi and Bijoy) from a field experiment which was conducted with normal sowing (sowing at November 30) and late sowing (sowing at December 30). In normal sowing, the grain weight per main stem was maximum in Bijoy (2.167 g). In late sown condition, grain weight per stem was the maximum in Bijoy and husk weight was found to be the maximum in Shatabdi. Bijoy produced the highest grain yield both under normal sowing and late sown mediated heat stressed condition. Considering all, Bijoy was identified as the best performing variety amongst all and Sufi was the worst one considering specifically the yield components and yield.

Hussain *et al.* (2010) conducted an experiment to assess the growth and yield response of three wheat varieties (Inqalab-91, Kharchia and Parwaz-94) under different seeding densities *viz.* 100, 125 and 150 kg ha^{-1}. The varieties differed significantly in respect to the yield contributing parameters and yield. Wheat variety Inqalab-91 when sown @ 150 kg ha^{-1} seeding density, gave the highest yield.

Alam *et al.* (2008) carried out a research work with twenty wheat varieties / lines to study the effect of source-sink manipulation on grain yield in wheat. Significant variations among the genotypes were observed for grain yield in main spike. Removal of flag leaf caused decrease in grain yield in main spike by 16.88%. Similarly, removal of all leaves caused reduction of grain yield in main spike by 27.92%. On the other hand, removal of 50% spikelet decreased 37.01% in grain yield in main spike. Similarly, 25% spikelets removal reduced grain yield main spike by 23.38%. The variety / lines BL-1020, Ananda and Akbar showed higher decrease in grain yield in main spike due to defoliation treatment.

Mehmet and Telat (2006) conducted field trials in two locations over two years to observe the adaptation and stability statistics of 20 bread wheat genotypes for yield performances. There were differences in stability performances among the genotypes for the trait of grain yield. The instability for grain yield was resulted from not only the mean squares of deviation from regression but also from the differences among regression coefficients of genotypes.

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

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

BARI (2003) conducted an experiment to test varietal performance of different wheat varieties and reported that Shatabdi produced the highest grain yield (3.20 t ha^{-1}) followed by Gourab (3.13 t ha^{-1}) and the lowest yield was produced by Kanchan (2.96 t ha^{-1}).

WRC (2003) conducted an experiment in Heat Tolerant Screening Nursery in Barisal region with 50 advance lines / varieties of wheat. The descending sequence of grain yield among the advanced varieties / lines was as follows–E50 (3.94 t ha^{-1}), BAW 1048 (3.85 t ha^{-1}), BAW 1021 (3.64 t ha^{-1}), BAW 1024 (3.60 t ha^{-1}) and E45 (3.58 t ha^{-1}). Among the varieties released from BARI (WRC), Protiva showed the maximum yield (2.97 t ha^{-1}).

Zhu *et al.* (1999) carried out several experiments with 100 varieties of wheat in Zhejiang since 1954 and 27 of these have been grown over 34,000 ha. Yields had increased greatly because of selective breeding. In 1990, mean production was 1.60 t ha^{-1}, 1.40 times higher than in 1959. In 1994, production was 2.52 t ha^{-1}, 57% higher than in 1970, while in 1997 it reached to 2.94 t ha^{-1}. Varieties had also been selected for quality as well as yield improvement.

Litvinenko (1998) reported that winter wheat with high grain quality for bread making is produced in Southern Ukraine. Wheat breeding began more than 80 years ago. Over this time, seven wheat varieties were selected where yield potential increased from 2.73 t ha^{-1} to 6.74 t ha^{-1}. This increase was due to a decrease in photoperiodic sensitivity and the introduction of semi-dwarf genes.

Genes for photoperiodic sensitivity (Ppd) and vernalization requirement (Vrn) were combined and the effect of those genes on grain yield, frost and drought resistance and growth and development rate of plant in autumn and early spring were studied. Breeding was carried out, utilising traditional and non-traditional methods such as anther culture, biochemical and molecular markers and screening in artificial environments using phytotrons. This approach resulted in the release of several winter wheat varieties with high yield potentials and well-expressed adaptation features.

Srivastava *et al.* (1998) conducted an experiment with nine wheat varieties promising for rainfed conditions, together with their 36 F_1 hybrids. Data were recorded on vegetative growth period, grain development period, flag leaf area (cm^2), Number of spikelets spike^{-1} and grain yield plant^{-1}. The genotypes were grouped into 10 clusters. Promising crosses for rainfed conditions were WL 2265 × P20302, CPAN 1992 × P20302, WL 2265 × HDR 87 and WL 2265 × CPAN 1992.

Arabinda *et al.* (1994) observed that the grain yield was significantly affected by different varieties. The genotype CB-15 showed higher grain yield (3.70 ha^{-1}) compared to other varieties.

Bakhshi *et al.* (1992) carried out field experiments with eight bread-wheat and seven durum-wheat varieties sown on 1st or 15 November or 15 December, and given 0, 40, 80 or 120 kg N ha^{-1} with one or two irrigation. Grain yield was the highest when wheat was sown on 1st November with 120 kg N ha^{-1} and two irrigations. Varieties Raj 3037, HD-4594, WL-711 and WH-841 gave the highest grain yield among the eight wheat varieties.

2.4 Effect of cow dung manipulation on plant growth parameters of wheat

Hassan (2018) conducted an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung 10 t ha^{-1}, F_2 = vermicompost 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of organic fertilizer, the tallest plant at different days after sowing (24.84, 35.77, 56.60 and 78.42 cm, respectively) and the highest number of effective tillers $hill^{-1}$ (3.81) was recorded from (cow dung 10 t ha^{-1}) and lowest from control.

Roy *et al.* (2015) carried out an experiment during the winter season to study the effect of tillage intensity, fertilizer and cow dung on soil water conservation, yield and protein content of wheat. The experiment was laid out in a split-plot design with three tillage treatments (T_1, T_2 and T_3) in the main plots and fertilizer with cow dung treatments in the sub-plots and replicated thrice. The recommended high yielding wheat variety, Shatabdi was used as a test crop, which is recommended to cultivate in winter season. The tillage treatments were: one passing of a power tiller (T_1), two passing of a power tiller (T_2) and three passing of a power tiller (T_3). Fertilizer and cow dung treatments were, F: Recommended dose of fertilizer@ 100 kg N (urea 46% N) ha^{-1}, 75 kg K (MP 50% K) ha^{-1}, 25 kg P (TSP 20% P) ha^{-1}, 13 kg S (gypsum 18% S) ha^{-1}, 2 kg Zn (zinc oxide 78% Zn) ha^{-1}, 1 kg B (boric acid 17% B) ha^{-1} and FCD: 60% of F + cow dung @ 5 t ha^{-1} (1.13% N, 0.27% P, 1.18% K, 0.15% S and 58 ppm Zn). The plant height of wheat was significantly changed by the addition of fertilizers and cow dung. The tallest plant (92.80 cm) and maximum number of effective tillers $plant^{-1}$ (4.01) was observed under FCD treatment. The shortest plant (89.40 cm) and minimum number of effective tillers $plant^{-1}$ (3.18) was found under F treatment.

Islam *et al.* (2014) conducted an experiment during November 2011 to March 2012 to evaluate the effect of integrated use of manures and fertilizers on the growth, yield and nutrient uptake by wheat. There were six treatments such as

T_0: (control), T_1: [STB (Soil Test Basis)-CF (Chemical fertilizer) (HYG = High yield goal)], T_2: [CD (cow dung) + STB-CF (HYG)], T_3: [PM (Poultry manure) + STB-CF (HYG)], T_4: [COM (Compost) + STB-CF (COM)] and T_5: [FP (Farmers' practice)]. Kanchan, a high yielding variety of wheat was used in this experiment as test crop. The integrated use of manures and fertilizers significantly influenced the yield attributes as well as grain and straw yields of wheat. The treatment T_1 [STB-CF (HYG)] produced the tallest plant of 90.17 cm which was identical with T_3 [PM + STB-CF (HYG)] and the lowest value was found in control. The maximum number of effective tillers hill^{-1} (3.85) was obtained in T_1 and the minimum number of effective tillers (2.80) was observed in T_0. The treatments T_0, T_2 and T_4 showed statistically similar number of effective tillers hill^{-1}.

Khan *et al.* (2007) from their experiment titled 'Effect of integrated nutrient management on crop yields in rice-wheat cropping system' reported that combined application of manures and fertilizers increased the plant height and number of tillers hill^{-1} in wheat.

2.5 Effect of cow dung manipulation on yield contributing parameters of wheat

Hassan (2018) conducted an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung 10 t ha^{-1}, F_2 = vermicompost 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of organic fertilizer, the highest number of spikelets spike^{-1} (16.33), the highest number of grains spikelet^{-1} (7.67), highest number of grains spike^{-1} (37.02), the longest spike (13.33 cm) and the maximum weight of 1000-grains (44.93 g) were recorded from F_1 (cow dung @ 10 t ha^{-1}) and the lowest from control.

Roy *et al.* (2015) carried out an experiment during the winter season to study the effect of tillage intensity, fertilizer and cow dung on soil water conservation, yield and protein content of wheat. The experiment was laid out in a split-plot design with three tillage treatments (T_1, T_2 and T_3) in the main plots and fertilizer with cow dung treatments in the sub-plots and replicated thrice. The recommended high yielding wheat variety, Shatabdi was used as a test crop, which is recommended to cultivate in winter season. The tillage treatments were: one passing of a power tiller (T_1), two passing of a power tiller (T_2) and three passing of a power tiller (T_3). Fertilizer and cow dung treatments were, F: Recommended dose of fertilizer@ 100 kg N (urea 46% N) ha^{-1}, 75 kg K (MP 50% K) ha^{-1}, 25 kg P (TSP 20% P) ha^{-1}, 13 kg S (gypsum 18% S) ha^{-1}, 2 kg Zn (zinc oxide 78% Zn) ha^{-1}, 1 kg B (boric acid 17% B) ha^{-1} and FCD: 60% of F + cow dung @ 5 t ha^{-1} (1.13% N, 0.27% P, 1.18% K, 0.15% S and 58 ppm Zn). Application of fertilizers and cow dung influenced the number of spikelets and grains $spike^{-1}$, spike length and weight of 1000-grains. The maximum number of spikelets $spike^{-1}$ (18.16), maximum number of grains $spike^{-1}$ (44.42), the longest spike of wheat (10.69 cm) and maximum weight of 1000-grains (45.97g) was recorded under the FCD treatment and the minimum number of spikelets $spike^{-1}$ (16.57), minimum number of grains $spike^{-1}$ (39.36), the shortest spike of wheat (9.77 cm) and minimum weight of 1000-grains (42.73 g) was recorded in the F treatment.

Islam *et al.* (2014) set up an experiment to evaluate the effect of integrated use of manures and fertilizers on the growth, yield and nutrient uptake by wheat. There were six treatments such as T_0: (control), T_1: [STB (Soil Test Basis)-CF (Chemical fertilizer) (HYG = High yield goal)], T_2: [CD (cow dung) + STB-CF (HYG)], T_3: [PM (Poultry manure) + STB-CF (HYG)], T_4: [COM (Compost) + STB-CF (COM)] and T_5: [FP (Farmers' practice)]. Kanchan, a high yielding variety of wheat was used in this experiment as test crop. The integrated use of manures and fertilizers significantly influenced the yield attributes of wheat. The number of spikelets spike^{-1} due to different treatments ranged from 27.28 to 52.46 and the maximum number was observed in the treatment T_1. The minimum number of spikelets spike^{-1} (27.28) was found in control. The longest spike (11.89 cm) was found in T_5 (farmers' practices) which was statistically similar with T_1. The treatments T_2, T_3 and T_4 were identical in producing spike length of wheat with the values of 10.91 cm, 10.69 cm and 10.32 cm, respectively. The shortest spike of 8.585 cm was obtained in control. The weight of 1000-grains ranged from 53.16 g to 50.72 g. All the treatments produced significantly higher weight of 1000-grains over control.

Singh *et al.* (2002) carried out an experiment to study the response of late sown wheat to seed rate and nitrogen. They reported that combined application of manures and fertilizers increased length of spike in wheat plant.

2.6 Effect of cow dung manipulation on yield parameters of wheat

Hassan (2018) set up an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung 10 t ha^{-1}, F_2 = vermicompost 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of organic fertilizer, the highest grain yield (4.39 g plant^{-1}), the highest straw yield (4.69 g plant^{-1}), highest biological yield (9.08 g plant^{-1}) and the highest harvest index (48.35%) were recorded from cow dung @ 10 t ha^{-1} and lowest from control.

Roy *et al.* (2015) carried out an experiment during the winter season to study the effect of tillage intensity, fertilizer and cow dung on soil water conservation, yield and protein content of wheat. The experiment was laid out in a split-plot design with three tillage treatments (T_1, T_2 and T_3) in the main plots and fertilizer with cow dung treatments in the sub-plots and replicated thrice. The recommended high yielding wheat variety, Shatabdi was used as a test crop, which is recommended to cultivate in winter season. The tillage treatments were: one passing of a power tiller (T_1), two passing of a power tiller (T_2) and three passing of a power tiller (T_3). Fertilizer and cow dung treatments were, F: Recommended dose of fertilizer@ 100 kg N (Urea 46% N) ha^{-1}, 75 kg K (MP 50% K) ha^{-1}, 25 kg P (TSP 20% P) ha^{-1}, 13 kg S (Gypsum 18% S) ha^{-1}, 2 kg Zn (Zinc oxide 78% Zn) ha^{-1}, 1 kg B (Boric acid 17% B) ha^{-1} and FCD: 60% of F + cow dung @ 5 t ha^{-1} (1.13% N, 0.27% P, 1.18% K, 0.15% S and 58 ppm Zn). Application of fertilizer and cow dung showed a significant influence on grain and straw yield. The highest grain yield of 3.82 t ha^{-1} and the highest straw yield of 8.11 t ha^{-1} was recorded under FCD treatment while the lowest grain yield of 3.26 t ha^{-1} and the lowest straw yield of 7.23 t ha^{-1} was recorded under F treatment.

Islam *et al.* (2014) conducted an experiment to evaluate the effect of integrated use of manures and fertilizers on the growth, yield and nutrient uptake by wheat. There were six treatments such as T_0: (control), T_1: [STB (Soil Test Basis)-CF (Chemical fertilizer) (HYG = High yield goal)], T_2: [CD (cow dung) + STB-CF (HYG)], T_3: [PM (Poultry manure) + STB-CF (HYG)], T_4: [COM (Compost) + STB-CF (COM)] and T_5: [FP (Farmers' practice)]. Kanchan, a high yielding variety of wheat was used in this experiment as test crop. The integrated use of manures and fertilizers significantly influenced the yield attributes as well as grain and straw yields of wheat. The grain and straw yield of wheat varied significantly due to the integrated use of cow dung, compost, poultry manures and NPKS fertilizers. The highest grain yield (4362 kg ha^{-1}) (90.4% increase over control) was observed in T_3 [PM+ STB-CF (HYG)] and the lowest value

(2291 kg ha^{-1}) was recorded in T_0 (control). The grain yield produced by T_1 [STB-CF (HYG)] was statistically similar with T_2 [CD + STB-CF (HYG)], T_3, T_4 [COM + STB-CF (HYG)] and T_5 [FP (Farmers' practice)] although there was a numerical variation in grain yield among the treatments. Based on grain yield, the treatments were ranked in order of $T_3 > T_1 > T_2 > T_4 > T_5 > T_0$. With same recommended fertilizer doses poultry manure treated plots gave higher grain yield than cow dung and compost treated plots. This might be due to the presence of uric acids in poultry manure that hastens the release of nutrients from poultry manure than compost and cow dung. The increase in grain yield over control ranged from 74.38% to 90.40% where the highest increase was obtained in T_3 and the lowest one was obtained in T_5. The NPKS uptake by wheat was markedly influenced by combined use of manures and fertilizers and the treatment T_3 demonstrated superior performance to other treatments. The maximum straw yield of 5492 kg ha^{-1} (84.79% increase over control) was found in T_3 [PM + STB - CF (HYG)] and the minimum value of 2972 kg ha^{-1} was noted in T_0 (control). The treatment was ranked in the order of $T_3 > T_2 > T_4 > T_1 > T_5 > T_0$ in terms of straw yield. Regarding the percent increase of straw yield, the highest increase (84.79%) was noted in T_3 and the lowest increase (47.22%) was observed in T_5 FP [farmers' practices].

Akhtar *et al.* (2011) from their experiment titled 'Improvement in nutrient uptake and yield of wheat by combined use of urea and compost' observed that combined application of organic manure and fertilizers significantly increased the straw yield of wheat.

Bodruzzaman *et al.* (2010) set up an experiment to study the long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern. The researcher found increased grain yield of wheat with the application of organic manures and fertilizers in an integrated way.

Yakub *et al.* (2010) conducted an experiment to observe the induction of mungbean [*Vigna radiata* (L.) Wilczek] as a grain legume in the annual rice-wheat double cropping system. Significant residual effects of manuring were observed on the subsequent wheat crop showing higher grain yield (21% increase), higher straw yield (15% increase) and grain N uptake (29% increase) of wheat by applying urea-N and manures in previous rice crop.

Asit *et al.* (2007) from their experiment on the effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages found grain yield of wheat increased with integrated application of organic manures and fertilizers.

Haque *et al.* (2001) carried out an experiment to observe the integrated nutrient management in relation of soil fertility and yield sustainability under Wheat-Mung-T. Aman cropping pattern. The researcher reported increase in grain yield of wheat where organic manures and fertilizers were applied in an integrated way.

2.7 Effect of water stress on plant growth parameters of wheat

Hassan (2018) conducted an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung 10 t ha^{-1}, F_2 = vermicompost 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of water stress, the highest plant height at different days after sowing (23.31, 34.97, 53.72 and 75.07 cm respectively) were recorded from D_0 and the lowest from D_3. In case of interaction, the highest plant height at different days after sowing

(27.66, 48.10, 63.15 and 78.56 cm respectively) were recorded from F_1D_0 and the lowest from F_0D_3. In case of water stress, the highest number of effective tillers hill^{-1} (5.67) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest number of effective tillers hill^{-1} (7.67) was recorded from F_1D_0 and the lowest from F_0D_3.

Moumita (2017) carried out an experiment to study the effect of water stress and gibberellic acid on morpho-physiological parameters and yield of wheat. Split-plot design was used for the experiment. BARI Gom-30 was the test crop for the study. It was a two-factor experiment; Factor A (Main plot): Gibberellic acid (2) a. No gibberellic acid (G_0) and b. 100 ppm gibberellic acid (G_1); Factor B (Sub-plot): Water stress (8), a. Full stress condition (T_0), b. No stress (T_1), c. Stress at CRI stage (T_2), d. Stress at flowering stage (T_3), e. Stress at grain development stag (T_4), f. Stress at CRI and flowering stage (T_5), g. Stress at CRI and grain development stage (T_6) and h. Stress at flowering and grain development stage (T_7). Water stress had significant effect on different growth and yield parameters of wheat. Plant height significantly reduced due to water stress and it was showed that in T_0 treatment where no water was applied, found lowest height (63.487 cm) at harvest. The highest plant height (75.967 cm) was found during harvest in T_1 that was control (no stress was imposed). If effect of water stress is compared within different growth stage condition except T_0 and T_1, it was found that T_6 (stress at flowering and grain development) is more sensitive. In case of no stress condition (T_1) wheat gave higher tiller number (1.92) per plant and full stress condition (1.13), stress at CRI stage (1.25), stress at CRI stage + flowering stage (1.15), stress at CRI stage + grain development stage (1.26) gave lowest number of tillers per plant. From the experiment, it was found that minimum number of tillers was found in stress at CRI stage or CRI + other stage. Therefore, it is clear that water stress reduced the tiller number plant^{-1} and for wheat about 22.06%. Water stress at CRI stage is critical for tiller production. The highest dry matter weight plant^{-1} at harvest stage was in T_1 (8.4710 g) and the lowest dry matter weight plant^{-1} was in T_0 (5.4126 g).

Farzana (2014) set up a pot experiment to investigate the improvement of drought tolerance in wheat by exogenous application of proline. Two wheat varieties viz. BARI Gom-24 and BARI Gom-26 were used as test crop and the experiment was laid out in a randomized complete block design with three replications. Treatment combinations were the different levels of irrigation and proline. There were four levels of irrigation, viz. I_0 - control (recommended irrigations), I_1 - water stress at vegetative stage (irrigation missing at vegetative stage), I_2 - water stress at flowering stage (irrigation missing at flowering stage), and I_3 - water stress at vegetative and flowering stages (irrigation missing at both vegetative and flowering stages). There were three levels of proline (0, 25 and 50 mM) and denoted as P_0, P_{25} and P_{50}. Water stress caused significant reductions in growth of both wheat varieties by decreasing plant height.

Akram (2011) carried out a field experiment to study the growth and yield components of wheat under water stress of different growth stages. He found that when water stress was severe, number of tillers plant^{-1} reduced significantly.

Malik *et al.* (2010) conducted an experiment to study the effect of different irrigation regimes on grain yield of wheat. They showed that when single irrigation was given, tiller production was very poor. Maximum tillers m^{-2} were produced when five irrigations were applied.

Kabir *et al.* (2009) from their experiment titled as effect of seed rate and irrigation level on the performance of wheat cv. Gourab where four levels of irrigations were given in the experiment on wheat, found that number of tillers plant^{-1} was 9.81% higher in watered condition than the water stress. The maximum number of tillers plant^{-1} was gained when two irrigations were given and the lowest tiller number was found from no irrigation.

Subhani and Chowdhry (2000) from their experiment titled as ‘Correlation and path coefficient analysis in bread wheat under water stress and normal conditions' found that when water stress was severe, number of tillers plant^{-1} reduced significantly.

2.8 Effect of water stress on yield contributing parameters of wheat

Hassan (2018) carried out an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a completely randomized design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung @ 10 t ha^{-1}, F_2 = vermicompost @ 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of water stress, the highest number of spikelet spike^{-1} (17.67) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest number of spikelet spike^{-1} (18) was recorded from F_1D_0 and the lowest from F_0D_3. The highest number of grains spikelet^{-1} (8.33) and number of grains spike^{-1} (39.17) were recorded from D_0 and the lowest from D_3. In case of interaction, the highest number of grains spikelet^{-1} (9.33) and number of grains spike^{-1} (40.02) were recorded from F_1D_0 and the lowest from F_0D_3. The longest spike (14.33 cm) was recorded from D_0 and the shortest from D_3. In case of interaction, the longest spike (16.12 cm) was recorded from F_1D_0 and the shortest from F_0D_3. In case of water stress, the maximum weight of 1000-grains (45.14 g) was recorded from D_0 and the lowest from D_3. In case of interaction, the maximum weight of 1000-grains (48.37 g) was recorded from F_1D_0 and the lowest from F_0D_3.

Moumita (2017) conducted an experiment to study the effect of water stress and gibberellic acid on morpho-physiological parameters and yield of wheat. Split-plot design was used for the experiment. BARI Gom-30 was the test crop for the study. It was a two-factor experiment; Factor A (Main plot): Gibberellic acid (2) a. No gibberellic acid (G_0) and b. 100 ppm gibberellic acid (G_1); Factor B (Sub-plot): Water stress (8), a. Full stress condition (T_0), b. No stress (T_1), c. Stress at CRI stage (T_2), d. Stress at flowering stage (T_3), e. Stress at grain development stag (T_4), f. Stress at CRI and flowering stage (T_5), g. Stress at CRI and grain development stage (T_6) and h. Stress at flowering and grain development stage (T_7). Water stress had significant effect on different growth and yield parameters of wheat. Maximum number of spikelets spike^{-1} was found from T_1 (16.635) and the lowest number was from T_0 (11.972). About 41% number of spikelets reduced due to the water stress. Number of grains spike^{-1} was the maximum in T_1 (44.53) and the lowest value was found in T_0 (29.74). Water stress reduced the spike length in wheat; from the data it was found that spike length was the maximum in T_1 (15.56 cm) and the lowest value was found in T_0 (10.87 cm). Water stress reduced the spike length 43.14% than the no stress condition. The maximum weight of 1000-grains was found from T_1 (43.50 g) and the minimum weight was from T_0 (28.20). About 54% weight of 1000-grains was reduced due to the water stress.

Farzana (2014) conducted a pot experiment to investigate the improvement of drought tolerance in wheat by exogenous application of proline. Two wheat varieties viz. BARI Gom-24 and BARI Gom-26 were used as test crop and the experiment was laid out in a randomized complete block design with three replications. Treatment combinations were the different levels of irrigation and proline. There were four levels of irrigation, viz. I_0 - control (recommended irrigations), I_1 - water stress at vegetative stage (irrigation missing at vegetative stage), I_2 - water stress at flowering stage (irrigation missing at flowering stage), and I_3 - water stress at vegetative and flowering stages (irrigation missing at both vegetative and flowering stages). There were three levels of proline (0, 25 and 50 mM) and denoted as P_0, P_{25} and P_{50}. Water stress caused significant reductions in yield of both wheat varieties by decreasing number of grains spike^{-1}, weight of 1000-grains and reducing spike length.

Akram (2011) carried out a field experiment to study the growth and yield components of wheat under water stress at different growth stages. The researcher applied four level of stress. He found that number of spikelets spike^{-1} (17.83) and length of spike (11.57 cm) was higher where no stress was applied and it was lower where stress applied during stem elongation and anthesis period.

Kabir *et al.* (2009) set up an experiment with four level of irrigation to show the effect of yield and yield performance of wheat cv. Gourab under different level of irrigation. He found that number of spikelets spike^{-1} was increased about 11.59% than the water stressed condition.

Chandler and Singh (2008) from their experiment titled as 'Selection Criteria for Drought Tolerance in Spring Wheat (*Triticum aestivum* L.)' reported that spikelet of wheat became sterile due to water deficit at reproductive stage and as a result, number of grains per spike decreased.

Ozturk and Aydin (2004) set up an experiment to observe the effect of water stress at various growth stages on some quality characteristics of winter wheat. They applied full irrigation (FI), rainfed (R), early water stress (EWS), late water stress (LWS) and continuous water stress (CWS) condition. The reduction of number of grains per unit area was in EWS 44.4%, LWS 13.9% and CWS 54.9 % than FI. Weight of 1000-grains was the maximum in full irrigation (FI).

2.9 Effect of water stress on yield parameters of wheat

Hassan (2018) carried out an experiment during the Boro season to evaluate the impact of organic fertilizer to combat water stress of wheat. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: Different level of organic fertilizer [F_0 = control, F_1 = cow dung 10 t ha^{-1}, F_2 = vermicompost 7 t ha^{-1}] and Factor B: Different level of water stress [D_0 = control, D_1 = drought in crown root initiation stage (20–29 DAS), D_2 = drought in booting stage (45–54 DAS), D_3 = drought in anthesis stage (55–64 DAS)]. BARI Gom-28 was used as experimental crop. Significant variation was observed on growth, yield and yield contributing parameters. In case of water stress, the highest grain yield (4.72 g plant^{-1}) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest grain yield (4.89 g plant^{-1}) was recorded from F_1D_0 and the lowest from F_0D_3. The highest straw yield (5.05 g plant^{-1}) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest straw yield (5.18 g plant^{-1}) was recorded from F_1D_0 and the lowest from F_0D_3. In case of water stress, the highest biological yield (9.77 g plant^{-1}) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest biological yield (10.07 g plant^{-1}) was recorded from F_1D_0 and the lowest from F_0D_3. The highest harvest index (48.31%) was recorded from D_0 and the lowest from D_3. In case of interaction, the highest harvest index (48.56%) was recorded from F_1D_0 and the lowest from F_0D_3.

Moumita (2017) conducted an experiment to study the effect of water stress and gibberellic acid on morpho-physiological parameters and yield of wheat. Split-plot design was used for the experiment. BARI Gom-30 was the test crop for the study. It was a two-factor experiment; Factor A (Main plot): Gibberellic acid (2) a. No gibberellic acid (G_0) and b. 100 ppm gibberellic acid (G_1); Factor B (Sub-plot): Water stress (8), a. Full stress condition (T_0), b. No stress (T_1), c. Stress at CRI stage (T_2), d. Stress at flowering stage (T_3), e. Stress at grain development stag (T_4), f. Stress at CRI and flowering stage (T_5), g. Stress at CRI and grain development stage (T_6) and h. Stress at flowering and grain development stage (T_7). Water stress had significant effect on different growth and yield parameters of wheat. Maximum grain yield was found from T_1 (3.39 t ha^{-1}) and the lowest yield was from T_0 (1.854 t ha^{-1}). About 45% grain yield was reduced due to the water stress. The maximum straw weight was in T_1 (3.24 t ha^{-1}) and the lowest amount of straw was in T_0 (2.48 t ha^{-1}). In the experiment it was found that the maximum biological yield was observed in T_1 (7.72 t ha^{-1}) and the lowest amount of biological yield was in T_0 (4.91 t ha^{-1}). From the experiment, it was reported that maximum reduction of harvest index was in full water stress condition (37.70) but it was statistically similar with T_7 or stress at Flowering + grain development stage (37.10). The highest harvest index was found from T_1 (43.40).

Schneekloth *et al.* (2017) from their experiment on effect of irrigation on wheat observed that drought condition at tillering stage of wheat (when branching start) decreased yield up to 46%. Water stress during booting stage of wheat reduces up to 21% yield.

Akram (2011) carried out a field experiment to study the growth and yield components of wheat under water stress of different growth stages. The researcher applied four level of stress. He found about 22% yield reduction due to water stress.

Mushtaq *et al.* (2011) set up an experiment where two wheat genotypes *viz.* a) Mairaj-2008 and b) Fareed-2006 were used to evaluate the effect of drought introduced conditions at different crop growth stages according to the given irrigation schedules, i.e. (i): control (no drought), (ii): Irrigation skip at tillering (20–40 DAS), (iii): Irrigation skip at jointing (40–75 DAS), iv: Irrigation skip at spike emergence (75–90 DAS) and v: Irrigation skip at grain formation (105–115 DAS). Both of the wheat varieties have no genetic potential to withstand against drought. However, skipping irrigation at grain formation stage abruptly reduced the grain yield followed by skipping irrigation at tillering stage as compared to rest of the crop growth stages. Therefore, it was suggested that irrigation at grain formation and tillering stage should never be missed for successful crop husbandry.

Keyvan (2010) carried out an experiment to study the effects of water stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. Reduction in grain yield of wheat was found up to 25% and 46%, if water deficit after anthesis period and stem elongation stage, respectively.

Kabir *et al.* (2009) conducted an experiment with four level of irrigation to show the effect of yield and yield performance of wheat cv. Gourab under different level of irrigation. They reported that grain yield was increased 46.36% and straw yield was increased 26.89% than the water stressed condition. The researchers found that the numerical value of harvest index increased about 44.67% under irrigated conditions compared with the water stressed condition.

Banker *et al.* (2008) from their experiment titled as 'Effect of different irrigation treatment on growth and yield of wheat crop varieties' observed that watering at crown root initiation, tillering, jointing and flowering stage resulted in better yield.

IPCC (2007) from its assessment report show that water shortage at crown root initiation stage of wheat causes 27% yield loss. In the past few decades water stress drastically reduced production of wheat in many parts of Asia.

Zhang *et al.* (2006) from their experiment titled 'Yield performance of spring wheat improved by regulated deficit irrigation in an arid area' concluded that water stress should be avoided at the booting and heading of wheat to reduce yield loss.

Ozturk and Aydin (2004) set up an experiment to observe the effect of water stress at various growth stages on some quality characteristics of winter wheat. They applied full irrigation (FI), rainfed (R), early water stress (EWS), late water stress (LWS) and continuous water stress (CWS) condition. They reported that the highest yield (4.40 t ha^{-1}) in full-irrigated condition and the lowest yield (1.50 t ha^{-1}) was found in continuous stress condition.

Ramezanpoor and Dastfal (2004) carried out an experiment to evaluate bread and durum wheat cultivars tolerance to water stress. According to their report, wheat yield reduced by 21.8% and 40.7% due to 25% and 50% reduction of water consumption, respectively.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials used and methodology followed in the experiment with a brief description on experimental site, climate, soil, land preparation, planting materials, experimental design, land preparation, fertilizer application, irrigation and drainage, intercultural operation, data collection, data recording and their analysis. The details of investigation for achieving stated objectives are described below.

3.1 Description of the experimental site and materials

3.1.1 Location

The experiment was conducted at the net house of the department of agronomy, Sher-e- Bangla Agricultural University (SAU), Dhaka-1207, during the period from November 2018 to March 2019. The experimental area was located at $23^{0}41'$ N latitude and $90^{0}22'$ E longitude at a height of 8.6 m above the sea level **(Appendix I).**

3.1.2 Soil

The soil of the experimental site was clay loam belonging to the “Madhupur Tract” under AEZ 28. It was Deep Red Brown Terrace soil and belonged to “Nodda” cultivated series. The soil was silty clay in texture having pH of 6.7. The physical and chemical properties of the soil have been presented in **Appendix II.**

3.1.3 Climate

The experimental field was situated under sub-tropical climate; usually the rainfall is heavy during Kharif season, (April to September) and scanty in Rabi season (October to March). In Rabi season temperature is generally low and there is plenty of sunshine. The temperature tends to increase from February as the season proceeds towards kharif. Rainfall was almost nil during the period from November 2018 to March 2019 and scanty from February to March. The monthly total rainfall, average temperature during the study period (November to March) has been presented in **Appendix III.**

3.1.4 Planting materials

Two improved varieties of wheat - namely, BARI Gom-28 and BARI Gom-30 were used as planting material for the present study. These varieties are recommended for Rabi season in Bangladesh. These are slightly heat tolerant varieties and suitable for cultivation all over the country except saline area of southern belt. The feature of these varieties is presented below:

Name of Variety	:	BARI Gom-28
Height	:	95–100 cm
Maturity	:	100–105 days
Number of grains spike^{-1}	:	45–50
Grain colour	:	White and shiny
1000 grain weight	:	43–48 g
Yield	:	4.0–5.5 t ha^{-1}

Name of Variety	:	BARI Gom-30
Height	:	95–100 cm
Maturity	:	100–105 days
Number of grains spike^{-1}	:	45–50
Grain colour	:	White and shiny
1000 grain weight	:	44–46 g
Yield	:	4.0–5.0 t ha^{-1}

3.2 Treatments

Treatment: There were three factors included in the treatments as follows:

Factor A: Varieties - 2

i) V_1 = BARI Gom-28

ii) V_2 = BARI Gom-30

Factor B: cow dung levels - 5

i) C_0 = RDCF + Control (Without cow dung)

ii) C_1 = RDCF + 25% less of 10 t ha^{-1} cow dung

iii) C_2 = RDCF + 10 t ha^{-1} of cow dung

iv) C_3 = RDCF + 25% higher of 10 t ha^{-1} cow dung

v) C_4 = RDCF + 50% higher of 10 t ha^{-1} cow dung

- 10 t ha^{-1} cow dung and chemical fertilizers has been shown in section 3.3.1.

Factor C: Water stress imposition / Water deficit - 4

i) D_0 = Control (Normal irrigation was applied)

ii) D_1 = At crown root initiation stage

iii) D_2 = At booting stage

iv) D_3 = At anthesis stage

3.3 Details of the field operations

3.3.1 Pot preparation

Soil from SAU experimental field was collected on 6 November 2018 and breaks the clods as well to make the soil well tilth. Weeds, stubbles and crop residues were removed from the soil. A total 120 earthen pots measuring 22 cm diameter at top, 20 cm diameter at bottom and 18 cm height were collected from the local market. Each pot was filled up with 20 kg of soil. Urea, TSP, MoP, Gypsum, Zinc oxide and Boric acid were used at the rate of 200, 72, 66, 110, 4 and 5 kg ha^{-1}, respectively, which was 2.00, 0.72, 0.66, 1.10, 0.04 and 0.05 g pot^{-1}, respectively. Cow dung was applied @ 10 t ha^{-1}.

3.3.2 Experimental design

The experiment was laid out following randomized complete block design (RCBD) with three replications.

3.3.3 Fertilizer application

The whole amount of triple super phosphate (TSP), muriate of potash (MoP), Gypsum, Zinc oxide, Boric acid and one third of urea (as per treatment) were incorporated in each pot at the time of pot filling time. Rest two third of urea was applied in two equal splits at crown root initiation stage and spike initiation stage. Cow dung was applied during pot filling time as per treatment.

3.3.4 Seed collection and sowing

As per treatment, seeds of wheat varieties BARI Gom-28 and BARI Gom-30 were collected from Wheat Research Centre, Bangladesh Agriculture Research Institute (BARI) campus, Joydebpur, Gazipur. Before sowing, seeds were treated with Provex 200EC @ 2.5 g powder for kg^{-1} seed. Ten seeds were sown in each pot on 20 November 2018. After sowing, the seeds were covered with soil and lightly pressed by hand.

3.3.5 Intercultural operation

Following intercultural operations were done to ensure normal growth of the crop:

3.3.5.1 Irrigation

Irrigations were applied as per need of treatment of the experiment mentioned in section 3.2. In D_1 treatment, irrigation was not applied in those pots at crown root initiation stage. In D_2 treatment, irrigation was not applied in those pots at booting stage**.** In D_3, treatment, irrigation was not applied in those pots at anthesis stage**.**

3.3.5.2 Thinning and weeding

After 10 days of sowing, excess plants were thinned out keeping four plants in each pot. The pots were kept weed free. So, weeds were controlled as and when necessary.

3.3.5.3 Pest control

The crop was attacked by cereal aphid and grasshopper. The pots were sprayed with Diazinon to control the aphids and grass hopper at 35 and 60 DAS. Insecticides were applied to the pots in the afternoon.

3.3.6 Harvesting

The crop was harvested at different dates based on physiological maturity. The variety BARI Gom-28 was harvested on 8 March 2019 and BARI Gom-30 on 06 March 2019. Threshing, cleaning and drying of grains were done separately for each treatment. Properly dried grain and straw were weighed and converted into g plant^{-1} basis.

3.4 Data recording parameters

Data were collected on the following yield and yield components parameters:

A) Plant and yield contributing characters

1. Plant height (cm)
2. Number of effective tillers plant^{-1}
3. Spike length (cm)
4. Number of spikelets spike^{-1}
5. Number of grains spike^{-1}
6. 1000-grains weight (g)

B) Yield:

1. Grain yield (g plant^{-1})
2. Straw yield (g plant^{-1})
3. Biological yield (g plant^{-1})
4. Harvest index (%)

3.5 Procedure of data recording

3.5.1 Plant height

The plant height was measured from the ground level to top of the plant at harvest. The height of the four plants was measured and averaged them to get the height per plant basis.

3.5.2 Number of effective tillers plant^{-1}

Total effective tillers of the four plants were counted and average them to have tillers plant^{-1}.

3.5.3 Spike length (cm)

Spike length was measured with a meter scale from the base to the tip of the five spike and the average value was recorded as spike length.

3.5.4 Number of spikelets spike^{-1}

Total number of spikelets from the spike of four plants in each pot was counted and then averaged them to have number of spikelets spike^{-1}.

3.5.5 Number of grains spike^{-1}

The total grains of the spikes were counted and then averaged to have number of grains spike^{-1}.

3.5.6 Thousand grains weight (g)

Grain weight of each pot were taken with the help of a digital electrical balance and the grain weight was converted to thousand grains weight basis.

3.5.7 Grain yield (g plant^{-1})

Grains obtained from the four plants in each pot were dried and then weighed carefully. The results were expressed as g plant^{-1} basis on 14% moisture basis.

3.5.8 Straw yield (g plant^{-1})

Like grain yield, dry weight of straw for 4 plants in each pot was recorded and expressed as g plant^{-1} basis.

3.5.9 Biological yield (g plant^{-1})

Biological yield was calculated from the following formula:

Biological yield (g plant^{-1}) = Grain yield (g plant^{-1}) + Straw yield (g plant^{-1})

3.5.10 Harvest Index (%)

Harvest index was calculated on the ratio of economic yield (grain yield) to biological yield and expressed in terms of percentage. It was calculated by using the following formula (Gardner, *et al.*, 1985).

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

3.6 Statistical analysis

The collected data were statistically analyzed to obtain the level of significance using the computer-based software Statistics10 program. Mean difference among the treatments were tested with the least significant difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the influence of different levels of cow dung to mitigate water stress of wheat. The results obtained from the study have been presented, discussed and compared in this chapter through tables. The analytical results have been presented in Table 1 through Table 14. The interpretations are given under the following headings.

4.1 Effect of variety

4.1.1 Plant height

At harvesting time, plant height (cm) showed statistically significant variation due to effect of variety (Table 1). Across the varieties, plant height ranged from 68.98 to 71.13 cm in wheat. The variety BARI Gom-30 (V_2) produced the tallest plant (71.13 cm). On the other hand, the variety BARI Gom-28 (V_1) produced the dwarf stature plant at harvesting time (68.98 cm). The results obtained from the present study were in conformity with the findings of Tariq (2010), Rahman *et al.* (2009) and Mehmet and Telat (2006) who observed variation of plant height among the varieties, which may perhaps the genetic make-up of the varieties.

4.1.2 Number of effective tillers plant^{-1}

The result showed that the effect of variety on number of effective tillers plant^{-1} was significant at harvesting stage. Across the varieties, number of tillers ranged from 4.07 to 4.76 plant^{-1} (Table 1). The variety BARI Gom-30 (V_2) produced the maximum number of tillers plant^{-1} (4.76) and the variety BARI Gom-28 (V_1) produced the minimum number of tillers plant^{-1} (4.07) which indicates that BARI Gom-30 produced 16.95% higher tillers plant^{-1} over BARI Gom-28. The results obtained from the present study were similar to the findings of Nadim *et al.* (2012), Hussain *et al.* (2010) and Tariq (2010) who reported variations in number of tillers plant^{-1} among wheat varieties due to varietal differences.

4.1.3 Spike length

Spike length of wheat is a yield determining parameters. The result revealed that the effect of variety on spike length was statistically significant (Table 1). The variety BARI Gom-30 (V_2) produced the maximum length of spike (10.56 cm) whereas the variety BARI Gom-28 (V_1) produced the minimum length of spike (9.51 cm).

4.1.4 Number of spikelets spike^{-1}

There was no significant variation in the number of spikelets spike^{-1} (Table 1). Numerically, BARI Gom-30 (V_2) produced 15.01 spikelets spike^{-1} whereas it was 14.82 for BARI Gom-28 (V_1).

4.1.5 Number of grains spike^{-1}

The result indicated that the effect of variety on number of grains spike^{-1} was significant (Table 1). The variety BARI Gom-28 (V_1) produced the height number of grains spike^{-1} (28.26). On the other hand, the variety BARI Gom-30 (V_2) produced the lowest number of grains spike^{-1} (24.29) which means BARI Gom-28 produced 16.34% higher number seed than BARI Gom-30.

Table 1. Effect of variety on plant and yield contributing characters of wheat

Variety	Plant height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelet Spike^{-1} (no.)	Grains Spike^{-1} (no.)	Weight of 1000-grains (g)
V_1	68.98 b	4.07 b	9.51 b	14.82	28.26 a	43.89 b
V_2	71.13 a	4.76 a	10.56 a	15.01	24.29 b	46.67 a
LSD $_{(0.05)}$	**0.65**	**0.05**	**0.10**	**NS**	**0.30**	**0.44**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30

NS = Not significant

4.1.6 1000-grains weight

Weight of 1000 grains showed significant variation among the different varieties of wheat (Table 1). BARI Gom-30 (V_2) produced the maximum 1000-grain weight (46.67 g). On the other hand, the minimum 1000-grain weight (43.89 g) was obtained from BARI Gom-28 (V_1). It can be inferred from the result that BARI Gom-30 produced 6.33% heavier seed than BARI Gom-28. The result corroborates with the findings of Al-Musa *et al.* (2012) who reported that 1000 seed weight varied among the varieties. This may be due to the variation of genetic make-up of the varieties.

4.1.7 Grain yield

Wheat grain yield (g plant^{-1}) varied significantly for different varieties shown in Table 2. The highest grain yield (5.73 g plant^{-1}) was recorded by BARI Gom-30 (V_2) and the lowest (4.71 g plant^{-1}) was recorded from BARI Gom-28 (V_1). The result revealed that BARI Gom-30 out yielded over BARI Gom-28 by producing 21.66% higher yield, which may perhaps the higher yield attributing characters in BARI Gom-30 except number of grains spike^{-1}. The findings from the experimental work of Al-musa *et al.* (2012) and Hussain *et al.* (2012) supported the results of this study.

4.1.8 Straw yield

Wheat straw yield (g plant^{-1}) varied significantly for different varieties shown in Table 2. The maximum straw yield (7.08 g plant^{-1}) was recorded by BARI Gom-30 (V_1). On the other hand, the lowest straw yield (5.94 g plant^{-1}) was recorded from BARI Gom-28 (V_1).

4.1.9 Biological yield

The biological yield (g plant^{-1}) showed significant variation due to varieties (Table 2). It was observed that BARI Gom-30 (V_2) produced the maximum biological yield (13.55 g plant^{-1}) and the minimum biological yield (10.65 g plant^{-1}) was recorded from BARI Gom-28 (V_1).

4.1.10 Harvest index

Variety showed significant variation in harvest index (Table 2). BARI Gom-28 (V_1) showed the highest harvest index (44.13 %) whereas, the lowest harvest index (42.25 %) in BARI Gom-30 (V_2).

Table 2. Effect of variety on yield and harvest index of wheat

Variety	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
V_1	4.71 b	5.94 b	10.65 b	44.13 a
V_2	5.73 a	7.08 a	13.55 a	42.25 b
LSD $_{(0.05)}$	**0.064**	**0.076**	**0.15**	**0.39**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.
V_1 = BARI Gom-28 and V_2 = BARI Gom-30

4.2 Effect of cow dung

4.2.1 Plant height

The plant height of wheat was significantly influenced by different doses of cow dung at harvesting time (Table 3). The treatment C_4 (RDCF + 50% higher cow dung) produced the tallest plant (73.20 cm) which was statistically similar with C_3 (71.19 cm). On the other hand, the treatment C_0 (RDCF + no cow dung) produced the shortest plant (67.66 cm) which was statistically similar with C_1 (68.77 cm) and C_2 (69.46 cm). This result confirms the reports of Kobayashi *et al.* (1989) who observed organic manure had positive effect on plant height of wheat.

4.2.2 Number of effective tillers plant^{-1}

Significant variation was observed on the number of effective tillers plant^{-1} of wheat due to different levels of cow dung (Table 3). The treatment C_4 (RDCF + 50% higher cow dung) produced the highest number of effective tillers plant^{-1} (5.60) and C_0 (RDCF + no cow dung) produced the lowest value (3.27). The result indicates that C_4 treatment produced 71.25, 45.08 33.33 and 9.16% higher number of effective tillers plant^{-1} than C_0, C_1, C_2 and C_3 treatments, respectively.

4.2.3 Spike length

Significant variation was observed on spike length of wheat due to different doses of cow dung (Table 3). The treatment C_4 (RDCF + 50% higher cow dung) produced the longest length (10.82 cm) which was statistically similar with C_3 (10.49 cm). On the other hand, the C_0 (RDCF + no cow dung) produced the shortest length (9.80 cm) which was statistically similar with C_1 (9.90 cm).

4.2.4 Number of spikelets spike^{-1}

It was observed a significant variation on number of spikelet spike^{-1} of wheat due to different doses of cow dung (Table 3). The treatment C_4 (RDCF + 50% higher cow dung) produced the highest number of spikelet spike^{-1} (15.80) which was statistically similar with C_3 (15.60). Again, the C_0 (RDCF + no cow dung) produced the lowest value (14.18) which was statistically similar with C_1 (14.37). These results were supported by the findings of Hassan (2018) and Roy *et al.* (2015) by their experiments.

4.2.5 Number of grains spike^{-1}

Significant variation was observed on number of grains spike^{-1} of wheat due to the application of different levels of cow dung (Table 3). The treatment C_4 (RDCF + 50% higher cow dung) produced the maximum number of grains spike^{-1} (30.92) whereas, the C_0 (RDCF + no cow dung) produced the minimum (21.05). These results support the result of Rahman *et al.* (2009) who reported that the application of organic manure increased grains spike^{-1} of wheat.

Table 3. Effect of cow dung on plant and yield contributing characters of wheat

Cow dung dose	Plant height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
C_0	67.66 c	3.27 e	9.80 c	14.18 c	21.05 e	41.10 d
C_1	68.77 c	3.86 d	9.90 bc	14.37 bc	24.02 d	43.18 c
C_2	69.46 bc	4.20 c	10.14 b	14.70 b	26.54 c	45.12 b
C_3	71.19 ab	5.13 b	10.49 a	15.60 a	28.85 b	47.82 a
C_4	73.20 a	5.60 a	10.82 a	15.80 a	30.92 a	49.19 a
LSD $_{(0.05)}$	**1.0344**	**0.0860**	**0.1691**	**0.2163**	**0.4823**	**0.7001**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose

4.2.6 1000-grain weight

Significant variation was found on weight of 1000-grain of wheat due to the application of cow dung (Table 3). The treatment C_4 (RDCF + 50% higher cow dung of recommended dose) produced the maximum weight of 1000 grains (49.19 g) which was statistically similar with C_3 (47.82 g) whereas, the C_0 (RDCF + no cow dung) produced the minimum weight (41.10 g). These results support the results of Yang *et al.* (2004) who reported that 1000-grains weight was increased by the application of organic manure.

4.2.7 Grain yield

Different levels of cow dung application exerted significant variation on grain yield of wheat (Table 4). It can be inferred from the table that the treatment C_4 (RDCF + 50% higher cow dung of recommended dose) out yielded over C_0, C_1, C_2 and C_3 by producing 1.03, 0.71, 0.49 and 0.24 g plant^{-1} higher yield, respectively. However, the treatment C_4 (RDCF + 50% higher cow dung) produced the highest grain yield (5.72 g plant^{-1}). On the other hand, the C_0 (RDCF + no cow dung) produced the lowest grain yield (4.69 g plant^{-1}). These results support the findings of Rahman *et al.* (2009) who reported that the application of organic manure increased grain yield of wheat.

4.2.8 Straw yield

Significant variation was observed on straw yield of wheat due to different levels of cow dung treatments (Table 4). The treatment C_4 (RDCF + 50% higher cow dung) produced the highest straw yield (7.17 g plant^{-1}) which was statistically similar with C_3 (7.08 g plant^{-1}). On the other hand, the C_0 (RDCF + no cow dung) produced the lowest straw yield (6.53 g plant^{-1}) which was statistically similar with C_1 (6.76 g plant^{-1}).

4.2.9 Biological yield

Biological yield of wheat varied significantly due to different doses of cow dung application (Table 4). The treatment C_4 (RDCF + 50% higher cow dung) produced the maximum biological yield (12.88 g plant^{-1}) which was statistically similar with C_3 (12.59 g plant^{-1}) and the C_0 (RDCF + no cow dung) produced the lowest (11.23 g plant^{-1}) biological yield. These results are in conformity with the findings of Hassan (2018) who reported that cow dung application increased biological yield of wheat.

4.2.10 Harvest index

Harvest index of wheat showed significant variation due to different doses of cow dung (Table 4). The treatment C_4 (RDCF + 50% higher cow dung) produced the maximum harvest index (44.41%) which was statistically similar with C_3 (43.80%) and C_2 (43.37%). On the other hand, the C_0 (RDCF + no cow dung) produced the minimum harvest index (41.81%) which was statistically similar with C_1 (42.54%).

Table 4. Effect of cow dung on yield and harvest index of wheat

Cow dung doses	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield Plant^{-1} (g)	Harvest index (%)
C_0	4.69 e	6.53 c	11.23 c	41.81 c
C_1	5.01 d	6.76 bc	11.77 b	42.54 bc
C_2	5.23 c	6.81 b	12.04 b	43.37 ab
C_3	5.48 b	7.08 a	12.59 a	43.80 a
C_4	5.72 a	7.17 a	12.88 a	44.41 a
LSD $_{(0.05)}$	**0.1016**	**0.1211**	**0.2412**	**0.6318**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose

4.3 Effect of water stress

4.3.1 Plant height

Plant height was affected significantly due to imposition of water stress at different growth stages in wheat (Table 5). The treatment D_0 (no stress) produced the tallest plant (74.59 cm). On the other hand, the treatment D_3 (Water stress imposition) produced the shortest plant (65.02 cm). This result support the findings of Zhao *et al.* (2008) who stated that water stress affects both elongation as well as expansion of growth and inhibits cell enlargement more than cell division. It interrupts the germination of seedlings and reduces plant height.

4.3.2 Number of effective tillers plant^{-1}

Significant variation was clearly evident in case of number of effective tillers plant^{-1} of wheat due to different water stress levels (Table 5). The highest number of effective tillers plant^{-1} (5.13) was produced in the treatment D_0 (no stress) and the D_3 (Water stress imposition) treatment produced the lowest (3.43) value. This result support the findings of Zhao *et al.* (2008) who stated that water stress affects both elongation as well as expansion of growth and inhibits cell enlargement more than cell division. It hampers the germination of seedlings and reduces number of effective tillers plant^{-1} in wheat.

4.3.3 Spike length

Different Water stress imposition treatment had significant effect on spike length of wheat (Table 5). D_0 (no stress) treatment produced the longest spike length (10.92 cm) whereas, the D_3 (Water stress imposition) produced the shortest spike (9.50 cm). This result support the findings of Akram (2011) who reported that spike length was significantly affected by increasing moisture stress.

4.3.4 Number of spikelets spike^{-1}

A significant variation was found on number of spikelets spike^{-1} of wheat due to different levels of Water stress imposition treatment (Table 5). The highest number of spikelets spike^{-1} (15.60) was recorded from D_0 (no stress) treatment which was statistically similar with D_2 (15.29) whereas, the D_3 (Water stress imposition) produced the minimum number of spikelets spike^{-1} (14.04).

4.3.5 Number of grains spike^{-1}

Significant variation was observed on number of grains spike^{-1} of wheat due to differences in Water stress impositions (Table 5). D_0 (no Water stress imposition) treatment produced the highest number of grains spike^{-1} (31.07) and that of the lowest (21.41) was recorded from D_3 (Water stress imposition) treatment. This finding supports the results of Hassan (2018) who reported that moisture stress reduced number of grains spike^{-1} in wheat.

4.3.6 1000-grains weight

Weight of 1000-grains of wheat varied significantly due to differences in Water stress impositions (Table 5). The treatment D_0 (no stress) produced the maximum weight of 1000 grain (47.79 g) which was statistically similar with D_2 (46.77 g) whereas, the D_3 (Water stress imposition) produced the minimum weight (41.80 g) of 1000-grains of wheat. These results support the findings of Hassan (2018) who reported that moisture stress reduced weight of 1000-grains of wheat.

Table 5. Effect of water stress on plant and yield contributing characters of wheat

Water stress stage	Plant height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
D_0	74.59 a	5.13 a	10.92 a	15.60 a	31.07 a	47.79 a
D_1	72.46 b	4.24 c	10.04 c	14.73 b	24.60 c	44.78 b
D_2	68.15 c	4.85 b	10.46 b	15.29 a	28.03 b	46.77 a
D_3	65.02 d	3.43 d	9.50 d	14.04 c	21.41 d	41.80 c
LSD (0.05)	**0.9251**	**0.0769**	**0,1512**	**0.1935**	**0.4312**	**0.6261**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.3.7 Grain yield

Significant variation was observed on grain yield plant^{-1} of wheat due to imposition of water stress at different stages (Table 6). The treatment D_0 (no stress) produced the highest grain yield (6.06 g plant^{-1}). On the other hand, the D_3 (Water stress imposition) produced the lowest grain yield (4.36 g plant^{-1}) followed by D_2 (Water stress imposition) (5.62 g plant^{-1}). These results corroborate with the findings of Hassan (2018) and Moumita (2017) who reported that water stress resulted in decrease in grain yield of wheat.

4.3.8 Straw yield

Straw yield of wheat exerted significant variation due to different water stress level (Table 6). The maximum straw yield (7.51 g plant^{-1}) was recorded with the treatment D_0 (no stress) which was statistically similar with D_2 (7.31 g plant^{-1}). On the other hand, the treatment D_3 (Water stress imposition) produced the minimum straw yield (6.10 g plant^{-1}) of wheat.

4.3.9 Biological yield

There was a significant variation in biological yield of wheat due to different levels of water stresses (Table 6). Significantly the highest biological yield (13.56 g plant^{-1}) was recorded from the D_0 (no stress) treatment followed by D_2

(Water stress imposition) treatment (12.93 g plant^{-1}) and the D_3 (Water stress imposition) treatment produced the lowest biological yield (10.46 g plant^{-1}). Similar result was reported from Hassan (2018) and Moumita (2017) who observed that water stress resulted in decrease in total biomass.

4.3.10 Harvest index

Significant variation was observed on harvest index of wheat due to different water stress levels (Table 6). The treatment D_0 (no stress) produced the maximum harvest index (44.70 %) which was statistically similar with D_2 (43.60 %). On the other hand, the treatment D_3 (Water stress imposition) produced the minimum harvest index (41.76%) which was statistically similar with D_1 (42.69%).

Table 6. Effect of water stress on yield and harvest index of wheat

Water stress stage	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
D_0	6.06 a	7.51 a	13.56 a	44.70 a
D_1	4.86 c	6.58 b	11.46 c	42.69 bc
D_2	5.62 b	7.31 a	12.93 b	43.60 ab
D_3	4.36 d	6.10 c	10.46 d	41.76 c
LSD $_{(0.05)}$	**0.0909**	**0.1083**	**0.2157**	**0.5653**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.
Note: D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.4 Interaction effects of variety and cow dung

4.4.1 Plant height

Interaction effect of variety and different doses of cow dung showed significant variation on plant height of wheat at harvesting time (Table 7). The tallest plant (74.26 cm) was observed from the V_2C_4 treatment which was statistically similar with V_2C_3 (72.41 cm) and V_1C_4 (72.14 cm). On the other hand, the shortest plant

(66.65 cm) from V_1C_0 treatment which was statistically similar with V_1C_1 (68.07 cm), V_1C_2 (68.08 cm), V_2C_0 (68.68 cm) and V_2C_1 (69.47 cm).

4.4.2 Number of effective tillers plant^{-1}

Interaction effect of different variety and cow dung levels exhibited significant variation on number of effective tillers plant^{-1} of wheat (Table 7). The treatment V_2C_4 produced the highest number of effective tillers plant^{-1} (5.96) and the treatment combination V_1C_0 produced the lowest number of effective tillers plant^{-1} (2.94) of wheat.

4.4.3 Spike length

Spike length showed a significant variation due to interaction effect of different variety and different doses of cow dung treatment in wheat (Table 7). The treatment V_2C_4 produced the maximum length (11.24 cm) which was statistically similar with V_2C_3 (10.81 cm) whereas, V_1C_0 produced the lowest length (9.50 cm) which was statistically similar with V_1C_1 (9.70 cm) and V_1C_2 (9.81 cm).

4.4.4 Number of spikelets spike^{-1}

Different variety and different doses of cow dung interaction treatment showed significant variation on number of spikelet spike^{-1} of wheat (Table 7). The treatment V_2C_4 produced the highest number of spikelet spike^{-1} (15.84) which was statistically similar with V_1C_4 (15.72), V_1C_3 (15.58) and V_2C_3 (15.53). On the other hand, V_1C_0 produced the lowest number of spikelet spike^{-1} (14.07) which was statistically similar with V_1C_3 (14.24), V_2C_0 (14.30), V_1C_2 (14.48) and V_2C_1 (14.49) interactions.

4.4.5 Number of grains spike^{-1}

Interaction effect of variety and cow dung application levels showed significant variation on number of grains spike^{-1} of wheat (Table 7). The maximum number of grains spike^{-1} (32.56) was found by V_1C_4 combination treatment which was statistically similar with V_1C_3 (31.36) and the minimum number (19.73) was found by V_2C_0 combination treatment which was statistically similar with V_2C_1 and V_1C_0 (19.79 and 22.36, respectively).

Table 7. Interaction effects of variety and cow dung on plant and yield contributing characters of wheat

Interaction (Variety × Cow dung)	Plant height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
V_1C_0	66.65 e	2.94 h	9.50 f	14.07 c	22.36 e	39.74 f
V_1C_1	68.07 de	3.56 g	9.70 ef	14.24 c	26.25 c	42.08 e
V_1C_2	68.08 de	3.90 f	9.81 d-f	14.48 bc	28.78 b	43.08 de
V_1C_3	69.97 b-d	4.68 d	10.16 cd	15.58 a	31.36 a	46.80 c
V_1C_4	72.14 a-c	5.25 c	10.39 bc	15.72 a	32.56 a	47.79 bc
V_2C_0	68.68 de	3.60 g	10.13 c-e	14.30 bc	19.73 f	42.47 de
V_2C_1	69.47 c-e	4.17 e	10.11 c-e	14.49 bc	21.79 e	44.28 d
V_2C_2	70.84 b-d	4.49 d	10.50 bc	14.88 b	24.29 d	47.17 bc
V_2C_3	72.41 ab	5.58 b	10.81 ab	15.53 a	26.33 c	48.85 ab
V_2C_4	74.26 a	5.96 a	11.24 a	15.84 a	29.28 b	50.58 a
$LSD_{(0.05)}$	**1.46**	**0.12**	**0.23**	**0.30**	**0.68**	**0.99**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.
Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30

C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose

4.4.6 1000-grains weight

Interaction effect of variety and cow dung application levels showed significant variation on weight of 1000-grain of wheat (Table 7). The treatment V_2C_4 produced the highest weight of 1000-grain (50.58 g) which was statistically similar with V_2C_3 (48.85 g) whereas, the treatment combination of V_1C_0 produced the lowest weight (39.74 g).

4.4.7 Grain yield

Grain yield showed significant variation due to interaction effect of different variety and application of different levels of cow dung in wheat (Table 8). The interaction treatment V_2C_4 produced the highest grain yield (6.30 g plant^{-1}) which was statistically similar with V_2C_3 (6.05 g plant^{-1}) whereas, V_1C_0 produced the lowest (4.27 g plant^{-1}) grain yield.

4.4.8 Straw yield

Straw yield varied significantly due to interaction effect of different variety and application of different levels of cow dung treatment in wheat (Table 8). The maximum straw yield (8.11 g plant^{-1}) was found by V_2C_4 combination treatment which was statistically similar with V_2C_3 (8.05 g plant^{-1}) and V_2C_2 (7.78 g plant^{-1}). On the other hand, the minimum straw yield (5.64 g plant^{-1}) was found by V_1C_0 combination treatment which was statistically similar with V_1C_2 and V_1C_1 (5.85 and 5.87 g plant^{-1}, respectively).

4.4.9 Biological yield

A significant variation was found due to interaction effect of variety and different doses of cow dung on biological yield of wheat (Table 8). The treatment combination V_2C_4 produced the highest biological yield (14.41 g plant^{-1}) which was statistically similar with V_2C_3 (14.15 g plant^{-1}) whereas, the treatment combination of V_1C_0 produced the lowest yield (9.91 g plant^{-1}) which was statistically similar with V_1C_1 and V_1C_2 interactions (10.44 and 10.54 g plant^{-1}, respectively).

4.4.10 Harvest index

Harvest index exhibited significant variation due to interaction effect of variety and different doses of cow dung in wheat (Table 8). The treatment combination V_1C_4 gave the highest harvest index (45.21 %) which was statistically similar with V_1C_2, V_1C_3, V_1C_1 and V_2C_4 (44.43%, 44.43%, 43.61% and 43.60%, respectively). On the other hand, the treatment V_2C_0 produced the lowest harvest index (40.67%) which was statistically similar with V_2C_1 (41.47%) and V_2C_2 (42.32%).

Table 8. Interaction effects of variety and cow dung on yield and harvest index of wheat

Interaction (Variety × Cow dung)	Grain yield $plant^{-1}$ (g)	Straw yield $plant^{-1}$ (g)	Biological yield $plant^{-1}$ (g)	Harvest index (%)
V_1C_0	4.27 g	5.64 f	9.91 g	42.96 b-d
V_1C_1	4.57 f	5.87 ef	10.44 fg	43.61 a-c
V_1C_2	4.69 ef	5.85 ef	10.54 fg	44.43 ab
V_1C_3	4.91 de	6.12 de	11.03 ef	44.43 ab
V_1C_4	5.13 d	6.23 d	11.36 e	45.21 a
V_2C_0	5.12 d	7.43 c	12.54 d	40.67 e
V_2C_1	5.45 c	7.66 bc	13.11 cd	41.47 de
V_2C_2	5.78 b	7.78 ab	13.56 bc	42.32 c-e
V_2C_3	6.05 ab	8.05 a	14.15 ab	43.17 b-d
V_2C_4	6.30 a	8.11 a	14.41 a	43.60 a-c
$LSD_{(0.05)}$	**0.14**	**0.17**	**0.34**	**0.89**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30

C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose

4.5 Interaction effects of variety and water stress

4.5.1 Plant height

Significant interaction effect between the variety and different water stress was observed at harvesting time of plant height in wheat (Table 9). The tallest plant (75.77 cm) was obtained from the V_2D_0 combination which was statistically similar with V_2D_1 (74.18 cm) and V_1D_0 (73.41 cm). On the other hand, the shortest plant (64.46 cm) was obtained from the combination V_1D_3, which was statistically similar with V_2D_3 (65.59 cm) treatment combination.

4.5.2 Number of effective tillers plant $^{-1}$

Interaction effect between the variety and different water stress was significant on number of effective tillers plnat^{-1} in wheat (Table 9). The maximum number of effective tillers plant^{-1} (5.41) was obtained from the V_2D_0 combination. On the other hand, the minimum number of effective tillers plnat^{-1} (2.88) was obtained from the combination V_1D_3 which was statistically different from other combinations.

4.5.3 Spike length

Interaction effect of variety and different water stress had significant influence on spike length of wheat (Table 9). The result of the investigation showed that, the treatment combination V_2D_0 produced the maximum spike length (11.32 cm) and the treatment combination V_1D_3 produced the minimum ones (9.30 cm) which was statistically similar with V_1D_1 and V_2D_3 (9.70 cm and 9.70 cm, respectively).

4.5.4 Number of spikelets spike^{-1}

Number of spikelets spike^{-1} was significantly influenced by the interaction effect of variety and different water stress levels on wheat (Table 9). The highest number of spikelets spike^{-1} (15.70) was obtained from the V_2D_0 combination treatment which was statistically similar with V_1D_0, V_2D_2 and V_1D_2 (15.50, 15.40 and 15.19, respectively); whereas, the lowest number of spikelets spike^{-1} (13.84) was obtained from the V_1D_3 combination treatment which was statistically similar with V_2D_3 (14.24).

4.5.5 Number of grains spike^{-1}

Significant interaction effect between the variety and different water stress was observed on number of grains spike^{-1} in wheat (Table 9). The maximum number of grains spike^{-1} (34.10) was obtained from the V_1D_0 treatment combination whereas, the minimum number of grains spike^{-1} (20.11) was obtained from the V_2D_3 treatment combination.

Table 9. Interaction effects of variety and water stress on plant and yield contributing characters of wheat

Interaction (Variety × Water stress)	Plant height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
V_1D_0	73.41 a	4.86 c	10.53 b	15.50 a	34.10 a	45.32 cd
V_1D_1	70.75 b	3.94 e	9.70 de	14.75 bc	26.08 d	43.81 de
V_1D_2	67.31 cd	4.58 d	10.10 cd	15.19 ab	30.17 b	45.62 c
V_1D_3	64.46 e	2.88 f	9.30 e	13.84 d	22.70 e	40.84 f
V_2D_0	75.77 a	5.41 a	11.32 a	15.70 a	28.04 c	50.25 a
V_2D_1	74.18 a	4.53 d	10.39 bc	14.70 bc	23.09 e	45.75 c
V_2D_2	69.00 bc	5.11 b	10.81 b	15.40 a	25.90 d	47.91 c
V_2D_3	65.59 de	3.98 e	9.70 de	14.24 cd	20.11 f	42.76 e
LSD $_{(0.05)}$	**1.30**	**0.10**	**0.21**	**0.27**	**0.62**	**0.88**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30
D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.5.6 1000-grains weight

Interaction effect of variety and water stress had significant influence on 1000-grains weight of wheat (Table 9). The result of the investigation showed that, the treatment combination V_2D_0 produced the height weight of 1000 grains (50.25 g). On the other hand, the treatment combination V_1D_3 produced the lowest weight of 1000 grains (40.48 g).

4.5.7 Grain yield

Significant interaction effect between the variety and different water stress was observed on grain yield of wheat (Table 10). The maximum grain yield (6.72 g plant^{-1}) was obtained from the V_2D_0 combination which was followed by V_2D_2 (6.30 g plant^{-1}). On the other hand, the minimum grain yield (4.01 g plant^{-1}) was obtained from the V_1D_3 combination treatment.

4.5.8 Straw yield

Straw yield differed significantly due to interaction effect between variety and different levels of water stress on wheat (Table 10). The highest straw yield (8.57 g plant^{-1}) was obtained from the V_2D_0 combination, which was statistically similar with V_2D_2 (8.48 g plant^{-1}). On the other hand, the lowest straw yield (5.37 g plant^{-1}) was obtained from the combination of V_1D_3.

4.5.9 Biological yield

Biological yield was influenced significantly by the interaction effect of variety and different water stress (Table 10). The highest biological yield (15.29 g plant^{-1}) was obtained from the V_2D_0 which was statistically similar with V_2D_2 (14.78 g plant^{-1}) and the lowest biological yield (9.38 g plant^{-1}) was obtained from the V_1D_3 treatment combination.

4.5.10 Harvest index

Harvest index was significantly influenced by the interaction effect of different variety and water stress levels (Table 10). The maximum harvest index (45.50%) was obtained from the V_1D_0 which was statistically similar with V_1D_2 (44.74%) and V_2D_0 (43.91%). On the other hand, the minimum harvest index (40.86%) was obtained from the V_2D_3, which was statistically similar with V_2D_1 (41.77%).

Table 10. Interaction effects of variety and water stress on yield and harvest index of wheat

Interaction (Variety × Water stress)	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
V_1D_0	5.39 c	6.45 d	11.84 c	45.50 a
V_1D_1	4.50 e	5.81 f	10.31 e	43.62 bc
V_1D_2	4.95 d	6.14 e	11.08 d	44.74 ab
V_1D_3	4.01 f	5.37 g	9.38 f	42.66 cd
V_2D_0	6.72 a	8.57 a	15.29 a	43.91 a-c
V_2D_1	5.21 c	7.34 b	12.60 b	41.77 de
V_2D_2	6.30 b	8.48 a	14.78 a	42.45 cd
V_2D_3	4.72 de	6.82 c	11.54 cd	40.86 e
LSD $_{(0.05)}$	**0.12**	**0.15**	**0.30**	**0.79**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30
D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.6 Interaction effects of cow dung and water stress

4.6.1 Plant height

Interaction effect of different doses of cow dung and water stress showed significant variation on plant height of wheat at harvesting time (Table 11). The tallest plant (77.03 cm) was observed from the C_4D_0 treatment combination which was statistically similar with C_3D_0, C_4D_1, C_2D_0, C_1D_0 and C_3D_1 (75.30, 74.91, 74.10, 73.85 and 73.36 cm, respectively). On the other hand, the shortest plant (61.95 cm) was recorded from C_0D_3 treatment which was statistically similar with C_1D_3, C_2D_3 and C_0D_2 (62.75, 64.36 and 65.56 cm, respectively).

4.6.2 Number of effective tillers plant^{-1}

Significant variation on number of effective tillers plant^{-1} of wheat was observed due to interaction effect of different doses of cow dung and water stress (Table 11). The result revealed that the treatment C_4D_0 produced the highest number of effective tillers plant^{-1} (6.43) and C_0D_3 produced the lowest number (2.56) which was statistically similar with C_0D_1 (2.59).

4.6.3 Spike length

Interaction effect of different doses of cow dung and water stress levels showed significant variation on spike length of wheat (Table 11). The treatment C_4D_0 produced the highest length (11.53 cm) which was statistically similar with C_4D_2 (11.18 cm) and C_3D_0 (11.10 cm) whereas, C_0D_3 and C_1D_3 produced the lowest length (9.26 cm) which was statistically similar with C_2D_3 (9.31 cm), C_1D_1 (9.48 cm), C_0D_1 (9.60 cm), C_4D_3 (9.80 cm), C_3D_3 (9.81 cm) and C_0D_2 (9.92 cm) interactions.

4.6.4 Number of spikelets spike^{-1}

Number of spikelets spike^{-1} had significant effect due to interaction of different doses of cow dung and levels of water stress on wheat (Table 11). The treatment C_4D_0 produced the highest number of spikelet spike^{-1} (16.55) which was statistically similar with C_3D_0 (16.28), C_4D_2 (16.16) and C_3D_2 (15.89). On the other hand, C_1D_3 produced the lowest number of spikelet spike^{-1} (13.42) which was statistically similar with C_0D_3 (13.55), C_0D_1 (13.77), C_2D_3 (13.92) and C_1D_1 (14.18).

4.6.5 Number of grains spike^{-1}

Interaction effect of different doses of cow dung and water stress exerted significant variation on number of grains spike^{-1} of wheat (Table 11). The maximum number of grains spike^{-1} (36.88) was found by C_4D_0 combination treatment and the minimum number of grains spike^{-1} (19.75) was recorded from

C_0D_1 combination treatment which was statistically similar with C_1D_3 (19.91) and C_2D_3 (21.28).

Table 11. Interaction effects of cow dung and water stress on plant and yield contributing characters of wheat

Interaction (Cow dung × Water stress)	Plant Height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
C_0D_0	72.68 b-d	4.14 g-i	10.44 c-f	14.84 d-g	25.17 ef	44.22 ef
C_0D_1	70.47 c-f	2.59 lm	9.60 gh	13.77 ij	19.75 j	40.21 gh
C_0D_2	65.56 g-j	3.80 j	9.92 e-h	14.60 f-i	23.14 g-i	42.25 fg
C_0D_3	61.95 j	2.56 m	9.26 h	13.55 j	16.12 k	37.75 h
C_1D_0	73.85 a-c	4.49 ef	10.83 b-d	15.09 c-f	28.37 d	47.02 cd
C_1D_1	71.89 b-d	3.84 ij	9.48 gh	14.18 g-j	22.07 hi	42.29 fg
C_1D_2	66.59 f-i	4.22 f-h	10.00 e-g	14.77 e-h	25.73 e	44.82 d-f
C_1D_3	62.75 ij	2.91 l	9.26 h	13.42 j	19.91 j	38.60 h
C_2D_0	74.10 a-c	4.80 l	10.73 b-d	15.25 c-f	31.99 bc	44.54 d-f
C_2D_1	71.70 b-e	4.12 g-j	10.05 e-g	14.51 f-i	24.56 e-g	45.14 de
C_2D_2	67.69 e-h	4.55 ef	10.50 c-e	15.03 d-g	28.32 d	47.29 cd
C_2D_3	64.36 h-j	3.32 k	9.31 h	13.92 h-j	21.28 ij	43.54 ef
C_3D_0	75.30 ab	5.82 bc	11.10 a-c	16.28 ab	32.94 b	50.78 ab
C_3D_1	73.36 a-c	5.11 d	10.31 d-f	15.51 b-e	28.21 d	47.28 cd
C_3D_2	69.19 d-g	5.64 c	10.73 b-d	15.89 a-c	30.64 c	49.19 bc
C_3D_3	66.93 f-h	3.95 h-j	9.81 e-h	14.53 f-i	23.60 f-h	44.06 ef
C_4D_0	77.03 a	6.43 a	11.53 a	16.55 a	36.88 a	52.39 a
C_4D_1	74.91 ab	5.53 c	10.80 b-d	15.66 b-d	28.35 d	48.99 bc
C_4D_2	71.74 b-e	6.04 b	11.18 ab	16.16 ab	32.32 bc	50.29 ab
C_4D_3	69.13 d-g	4.41 fg	9.80 f-h	14.80 e-h	26.13 e	45.08 de
$LSD_{(0.05)}$	**2.07**	**0.17**	**0.33**	**0.43**	**0.96**	**1.39**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose.

D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.6.6 1000-grain weight

Weight of 1000-grains differed significantly due to interaction effect of different doses of cow dung and water stress on wheat (Table 11). The treatment combination C_4D_0 produced the highest weight of 1000-grains (52.39 g) which was statistically similar with C_4D_2 and C_3D_0 (50.29 and 50.78 g, respectively) whereas, the treatment combination of C_0D_3 produced the lowest weight of 1000-grains (37.75 g) which was statistically similar with C_1D_3 (38.60 g) and C_0D_1 (40.21 g).

4.6.7 Grain yield

Interaction effect of different doses of cow dung and water stress had significant variation on grain yield of wheat (Table 12). The treatment C_4D_0 produced the highest grain yield (6.63 g plant^{-1}) which was statistically similar with C_3D_0 (6.40 g plant^{-1}) whereas, C_0D_3 produced the lowest (3.91 g plant^{-1}) which was statistically similar with C_1D_3 (4.20 g plant^{-1}).

4.6.8 Straw yield

Application of different levels of cow dung and water stress levels exhibited significant variation on straw yield of wheat (Table 12). The maximum straw yield (7.80 g plant^{-1}) was found from C_3D_0 combination treatment which was statistically similar with C_4D_0 (7.75 g plant^{-1}), C_4D_2 (7.69 g plant^{-1}), C_2D_0 (7.64 g plant^{-1}) and C_3D_2 (7.52 g plant^{-1}). On the other hand, the minimum straw yield (5.75 g plant^{-1}) was recorded from C_0D_3 combination treatment which was statistically similar with C_1D_3 (6.03 g plant^{-1}), C_2D_3 (6.12 g plant^{-1}) and C_0D_1 (6.22 g plant^{-1}).

Table 12. Interaction effects of cow dung and water stress on yield and harvest index of wheat

Interaction (Cow dung × Water stress)	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
C_0D_0	5.39 ef	7.07 d-f	12.45 de	43.37 b-f
C_0D_1	4.36 ij	6.22 i-k	10.57 i-k	41.29 e-g
C_0D_2	5.12 fg	7.10 d-f	12.21 d-g	42.04 d-g
C_0D_3	3.91 k	5.75 k	9.66 k	40.56 g
C_1D_0	5.72 de	7.30 b-e	13.02 b-d	44.02 a-d
C_1D_1	4.76 g-i	6.53 g-i	11.28 f-i	42.21 d-g
C_1D_2	5.37 ef	7.21 c-f	12.58 c-e	42.83 b-g
C_1D_3	4.20 jk	6.03 jk	10.22 jk	41.10 fg
C_2D_0	6.16 bc	7.64 a-c	13.80 ab	44.73 a-c
C_2D_1	4.81 gh	6.46 g-j	11.27 g-i	42.74 b-g
C_2D_2	5.57 de	7.03 ef	12.60 c-e	44.12 a-d
C_2D_3	4.40 ij	6.12 i-k	10.52 i-k	41.93 d-g
C_3D_0	6.40 ab	7.80 a	14.20 a	45.16 ab
C_3D_1	5.05 fg	6.76 f-h	11.93 e-h	43.65 b-e
C_3D_2	5.91 cd	7.52 a-d	13.43 a-c	44.08 a-d
C_3D_3	4.57 h-j	6.25 ij	10.80 ij	42.33 c-g
C_4D_0	6.63 a	7.75 ab	14.35 a	46.25 a
C_4D_1	5.32 ef	6.92 e-g	12.24 d-f	43.58 b-f
C_4D_2	6.16 bc	7.69 a-c	13.85 ab	44.92 ab
C_4D_3	4.75 g-i	6.35 h-j	11.10 h-j	42.88 b-g
LSD $_{(0.05)}$	**0.20**	**0.24**	**0.48**	**1.26**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose.

D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.6.9 Biological yield

Biological yield varied significantly due to interaction effect of different doses of cow dung and water stress on wheat (Table 12). The treatment C_4D_0 produced the highest biological yield (14.35 g plant^{-1}) which was statistically similar with C_3D_0 (14.20 g plant^{-1}), C_4D_2 (13.85 g plant^{-1}), C_2D_0 (13.80 g plant^{-1}) and C_3D_2 (13.43 g plant^{-1}) whereas, the treatment combination of C_0D_3 produced the lowest biological yield (9.66 g plant^{-1}) which was statistically similar with C_1D_3, C_2D_3 and C_0D_1 (10.22, 10.52 and 10.57 g plant^{-1}, respectively).

4.6.10 Harvest index

Combined effect of different doses of cow dung and water stress showed significant variation on harvest index of wheat (Table 12). The treatment C_4D_0 produced the highest harvest index (46.25 %) which was statistically similar with C_3D_0, C_4D_2, C_2D_0, C_2D_2, C_3D_2 and C_1D_0 (45.16%, 44.92%, 44.73%, 44.12%, 44.08% and 44.02%, respectively). On the other hand, the treatment C_0D_3 produced the lowest harvest index (40.56%) which was statistically similar with C_1D_3, C_0D_1, C_2D_3, C_0D_2, C_1D_1, C_3D_3, C_2D_1, C_1D_2 and C_4D_3 (41.10%, 41.29%, 41.93%, 42.04%, 42.21%, 42.33%, 42.74%, 42.83% and 42.88%, respectively).

4.7 Interaction effects of variety, cow dung and water stress

4.7.1 Plant height

Significant interaction effect among the variety, different levels of cow dung and different water stress was observed on plant height at harvesting time of wheat (Table 13). The tallest plant (78.64 cm) was obtained from the $V_2C_4D_0$ combination which was statistically similar with $V_2C_3D_0$ (76.27 cm), $V_2C_4D_1$ (76.13 cm), $V_2C_2D_0$ (75.92 cm), $V_2C_3D_1$ (75.60 cm), $V_1C_4D_0$ (75.42 cm), $V_1C_3D_0$ (74.33 cm), $V_2C_1D_0$ (74.32 cm), $V_2C_2D_1$ (74.01 cm), $V_1C_4D_1$ (73.68 cm), $V_2C_0D_0$ (73.68 cm), $V_1C_1D_0$ (73.38 cm) and $V_2C_1D_1$ (72.86 cm). On the other hand, the shortest plant (61.40 cm) was obtained from the combination $V_1C_0D_3$ which was statistically similar with $V_1C_1D_3$ (62.08 cm), $V_2C_0D_3$ (62.50 cm), $V_2C_1D_3$ (63.42

cm), $V_2C_2D_3$ (64.17 cm), $V_1C_2D_3$ (64.54 cm), $V_1C_0D_2$ (64.85 cm), $V_1C_1D_2$ (65.92 cm), $V_1C_2D_2$ (66.11 cm), $V_1C_3D_3$ (66.21 cm) and $V_2C_0D_2$ (66.27 cm).

4.7.2 Number of effective tillers plant^{-1}

Interaction effect of variety, different levels of cow dung and different water stress showed significant variation on number of effective tillers plant^{-1} of wheat (Table 13). The treatment $V_2C_4D_0$ produced the highest number of effective tillers plant^{-1} (6.70) and interaction of $V_1C_0D_1$ produced the lowest number (2.22) which was statistically similar with $V_1C_0D_3$ (2.31) and $V_1C_1D_3$ (2.52).

4.7.3 Spike length

Spike length varied significantly due to interaction effect of variety, different levels of cow dung and different water stress on wheat (Table 13). The result of the investigation showed that, the treatment combination $V_2C_4D_0$ produced the maximum spike length (11.86 cm) which was statistically similar with $V_2C_3D_0$ (11.63 cm), $V_2C_4D_2$ (11.57 cm), $V_2C_2D_0$ (11.30 cm), $V_2C_4D_1$ (11.25 cm), $V_1C_4D_0$ (11.20 cm), $V_2C_1D_0$ (11.20 cm) and $V_2C_3D_2$ (11.07 cm) whereas, the treatment combination $V_1C_0D_3$ produced the minimum ones (9.01 cm) which was statistically similar with $V_1C_1D_3$ (9.10 cm), $V_1C_0D_1$ (9.16 cm), $V_2C_2D_3$ (9.20 cm), $V_1C_4D_3$ (9.27 cm), $V_1C_1D_1$ (9.30 cm), $V_2C_1D_3$ (9.42 cm), $V_1C_2D_3$ (9.43 cm), $V_1C_0D_2$ (9.47 cm), $V_2C_0D_3$ (9.50 cm), $V_1C_3D_3$ (9.63 cm), $V_1C_2D_1$ (9.64 cm), $V_2C_1D_1$ (9.67 cm) and $V_1C_1D_2$ (9.83 cm).

4.7.4 Number of spikelets spike^{-1}

Number of spikelets spike^{-1} was significantly influenced by the interaction effect of variety, different levels of cow dung and different water stress (Table 13). The highest number of spikelets spike^{-1} (16.76) was obtained from the $V_2C_4D_0$ combination treatment which was statistically similar with $V_1C_4D_0$ (16.33), $V_2C_3D_0$ (16.33), $V_2C_4D_2$ (16.23), $V_1C_3D_0$ (16.22), $V_1C_4D_2$ (16.10), $V_1C_3D_2$ (15.93), $V_2C_3D_2$ (15.86), $V_1C_4D_1$ (15.76), $V_1C_3D_1$ (15.66) and $V_2C_4D_1$ (15.56) whereas, the lowest (13.11) was obtained from the $V_1C_1D_3$ combination treatment which was statistically similar with $V_1C_0D_3$ (13.42), $V_1C_2D_3$ (13.45),

$V_2C_0D_3$ (13.67), $V_1C_0D_1$ (13.73), $V_2C_1D_2$ (13.73), $V_2C_0D_1$ (13.80), $V_2C_1D_1$ (14.13) and $V_1C_1D_1$ (14.23).

4.7.5 Number of grains spike^{-1}

Significant interaction effect between the variety, different levels of cow dung and different water stress was observed on number of grains spike^{-1} (Table 13). The maximum number of grains spike^{-1} (39.13) was obtained from the $V_1C_4D_0$ treatment combination and the minimum number of grains spike^{-1} (15.52) was obtained from the combination $V_2C_0D_3$ treatment which was statistically similar with $V_1C_0D_3$ (16.72).

4.7.6 1000-grains weight

Interaction effect of variety, different levels of cow dung and different water stress had significant influence on 1000-grains weight (Table 13). The result of the investigation showed that, the treatment combination $V_2C_4D_0$ produced the height weight of 1000 grains (53.20 g) which was statistically similar with $V_2C_3D_0$ (52.02 g), $V_2C_4D_2$ (51.03 g), $V_1C_4D_0$ (51.57 g), $V_2C_2D_0$ (51.21 g), $V_2C_4D_1$ (50.32 g), $V_1C_3D_0$ (49.53 g), $V_1C_4D_2$ (49.55 g) and $V_2C_3D_2$ (49.96 g). On the other hand, the treatment combination $V_1C_0D_3$ produced the lowest weight of 1000 grains (37.03 g) which was statistically similar with $V_1C_2D_0$ (37.87 g), $V_1C_1D_3$ (38.04 g), $V_2C_0D_3$ (38.46 g), $V_1C_0D_1$ (39.03 g), $V_2C_1D_3$ (39.15 g) and $V_1C_0D_2$ (40.35).

Table 13. Interaction effects of variety, cow dung and water stress on plant and yield contributing characters of wheat

Interaction (Variety × Cow dung × Water	Plant Height (cm)	Effective tillers plant^{-1} (no.)	Spike length (cm)	Spikelets spike^{-1} (no.)	Grains spike^{-1} (no.)	Weight of 1000-grains (g)
$V_1C_0D_0$	71.67 b-j	3.81 l-n	10.26 f-l	14.71 e-n	26.99 g-j	42.53 j-o
$V_1C_0D_1$	68.67 d-m	2.22 t	9.16 n-p	13.73 m-q	21.18 r-t	39.03 o-r
$V_1C_0D_2$	64.85 k-p	3.43 n-p	9.47 k-p	14.42 i-p	24.55 j-o	40.35 n-r
$V_1C_0D_3$	61.40 p	2.31 t	9.01 p	13.42 pq	16.72 vw	37.03 r
$V_1C_1D_0$	73.38 a-g	4.08 j-m	10.47 d-j	15.01 c-l	32.70 cd	45.09 g-m
$V_1C_1D_1$	70.91 b-j	3.77 l-o	9.30 m-p	14.23 j-q	23.51 l-r	41.15 m-q
$V_1C_1D_2$	65.92 j-p	3.88 l-m	9.83 i-p	14.63 g-p	27.50 f-i	44.05 i-n
$V_1C_1D_3$	62.08 op	2.52 st	9.10 op	13.11 q	21.30 q-s	38.04 qr
$V_1C_2D_0$	72.27 b-h	4.58 g-i	10.16 g-m	15.24 b-k	35.62 b	37.87 qr
$V_1C_2D_1$	69.38 d-l	4.02k-m	9.64 j-p	14.37 i-p	26.49 g-k	44.75 h-m
$V_1C_2D_2$	66.11 j-p	4.16 i-l	10.03 h-o	14.86 e-n	30.52 de	45.75 e-k
$V_1C_2D_3$	64.54 k-p	2.83 q-s	9.43 l-p	13.45 o-q	22.50 n-s	43.94 i-n
$V_1C_3D_0$	74.33 a-d	5.67 cd	10.57 d-j	16.22 a-c	36.07 b	49.53 a-f
$V_1C_3D_1$	71.12 b-j	4.45 h-k	10.06 h-n	15.66 a-h	30.54 de	46.44 d-j
$V_1C_3D_2$	68.23 e-n	5.53 c-e	10.40 d-k	15.93 a-e	33.78 bc	48.41 b-h
$V_1C_3D_3$	66.21 j-p	3.06 p-r	9.63 j-p	14.50 h-p	25.06 i-n	42.82 j-o
$V_1C_4D_0$	75.42 a-c	6.16 b	11.20 a-f	16.33 ab	39.13 a	51.57 a-c
$V_1C_4D_1$	73.68 a-f	5.25 d-f	10.30 e-l	15.76 a-g	28.70 e-g	47.66 c-i
$V_1C_4D_2$	71.42 b-j	5.91 bc	10.80 b-h	16.10 a-d	34.48 bc	49.55 a-e
$V_1C_4D_3$	68.47 d-m	3.66 m-o	9.27 m-p	14.70 f-n	27.93 e-h	42.38 k-p
$V_2C_0D_0$	73.68 a-f	4.47 h-k	10.63 c-i	14.96 d-l	23.35 m-r	45.90 e-k
$V_2C_0D_1$	72.27 b-h	2.95 p-s	10.02 h-o	13.80 l-q	18.32 uv	41.38 l-q
$V_2C_0D_2$	66.27 i-p	4.16 i-l	10.37 d-l	14.78 e-n	21.74 p-s	44.15 i-n
$V_2C_0D_3$	62.50 n-p	2.81 rs	9.50 k-p	13.67 n-q	15.52 w	38.46 p-r
$V_2C_1D_0$	74.32 a-d	4.89 f-h	11.20 a-f	15.16 b-k	24.05 k-p	48.94 b-g
$V_2C_1D_1$	72.86 a-h	3.91l-n	9.67 j-p	14.13 k-q	20.63 s-u	43.42 j-n
$V_2C_1D_2$	67.26 h-o	4.56 g-j	10.17 g-m	14.92 d-m	23.96 k-q	45.59 f-k
$V_2C_1D_3$	63.42 m-p	3.30 o-p	9.42 l-p	13.73 m-q	18.52 t-v	39.15 o-r
$V_2C_2D_0$	75.92 a-c	5.01 fg	11.30 a-d	15.26 b-k	28.36 e-h	51.21 a-c
$V_2C_2D_1$	74.01 a-e	4.21 i-l	10.47 d-j	14.66 f-o	22.63 n-s	45.52 g-k
$V_2C_2D_2$	69.27 d-l	4.93 f-h	10.90 b-h	15.20 b-k	26.13 g-l	48.82 b-g
$V_2C_2D_3$	64.17 l-p	3.81 l-m	9.20 n-p	14.40 i-p	20.05 s-u	43.13 j-n
$V_2C_3D_0$	76.27 ab	5.96 bc	11.63 ab	16.33 ab	29.81 ef	52.02 ab
$V_2C_3D_1$	75.60 a-c	5.77 bc	10.57 d-j	15.36 b-j	25.89 h-m	48.12 b-h
$V_2C_3D_2$	70.14 c-k	5.75 bc	11.07 a-g	15.86 a-f	27.50 f-i	49.96 a-d
$V_2C_3D_3$	67.64 g-o	4.83 f-h	10.00 h-o	14.56 g-p	22.13 o-s	45.30 g-l
$V_2C_4D_0$	78.64 a	6.70 a	11.86 a	16.76 a	34.63 bc	53.20 a
$V_2C_4D_1$	76.13 ab	5.81 bc	11.25 a-e	15.56 a-i	27.99 e-h	50.32 a-d
$V_2C_4D_2$	72.07 b-i	6.17 b	11.57 a-c	16.23 ab	30.16 d-f	51.03 a-c
$V_2C_4D_3$	70.22 c-k	5.15 ef	10.31 e-l	14.83 e-n	24.34 j-p	47.78 c-i
LSD $_{(0.05)}$	**2.93**	**0.24**	**0.48**	**0.61**	**1.36**	**1.97**
CV (%)	**5.11**	**6.75**	**5.72**	**5.02**	**6.36**	**5.35**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.
Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30
C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose
D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.7.7 Grain yield

Interaction effect of variety, different levels of cow dung and different water stress showed significant variation on grain yield of wheat (Table 14). The treatment $V_2C_4D_0$ produced the highest grain yield (7.32 g $plant^{-1}$) which was **statistically** similar with $V_2C_3D_0$ (7.17 g $plant^{-1}$), whereas, $V_1C_0D_3$ produced the lowest (3.51 g $plant^{-1}$) grain yield.

4.7.8 Straw yield

Significant interaction effect between the variety, different levels of cow dung and different water stress was observed on straw yield (Table 14). The height straw yield (8.99 g $plant^{-1}$) was obtained from the $V_2C_3D_0$ combination which was statistically similar with $V_2C_4D_2$ (8.90 g $plant^{-1}$), $V_2C_4D_0$ (8.73 g $plant^{-1}$), $V_2C_2D_0$ (8.71 g $plant^{-1}$), $V_2C_3D_2$ (8.69 g $plant^{-1}$) and $V_2C_2D_2$ (8.37 g $plant^{-1}$). On the other hand, the lowest straw yield (4.95 g $plant^{-1}$) was obtained from the combination $V_1C_0D_3$ which was statistically similar with $V_1C_1D_3$ (5.25 g $plant^{-1}$), $V_1C_2D_3$ (5.42 g $plant^{-1}$), $V_1C_0D_1$ (5.54 g $plant^{-1}$) and $V_1C_3D_3$ (5.58 g $plant^{-1}$).

Table 14. Interaction effects of variety, cow dung and water stress on and yield and harvest index of wheat

Interaction (Variety × Cow dung × Water stress)	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
$V_1C_0D_0$	4.82 j-p	6.04 m-s	10.86 m-r	44.38 a-h
$V_1C_0D_1$	4.13 rs	5.54 r-u	9.67 r-t	42.71 b-l
$V_1C_0D_2$	4.61 l-r	6.04 m-s	10.65 n-s	43.25 b-k
$V_1C_0D_3$	3.51 t	4.95 u	8.46 u	41.49 f-l
$V_1C_1D_0$	5.13 g-m	6.30 k-q	11.43 j-p	44.88 a-f
$V_1C_1D_1$	4.50 n-r	5.80 o-t	10.30 o-s	43.56 a-i
$V_1C_1D_2$	4.77 k-p	6.13 l-r	10.90 l-r	43.76 a-i
$V_1C_1D_3$	3.86 t	5.25 tu	9.11 tu	42.22 d-l
$V_1C_2D_0$	5.45 e-i	6.57 i-n	12.02 i-m	45.38 a-e
$V_1C_2D_1$	4.41 o-s	5.71 p-t	10.12 p-t	43.57 a-i
$V_1C_2D_2$	4.82 j-p	5.69 p-t	10.51 n-s	45.86 a-c
$V_1C_2D_3$	4.07 st	5.42 s-u	9.49 s-u	42.89 b-l
$V_1C_3D_0$	5.62 e-g	6.61 h-n	12.23 h-l	45.95 ab
$V_1C_3D_1$	4.62 l-r	5.93 n-t	10.55 n-s	43.78 a-i
$V_1C_3D_2$	5.18 g-l	6.35 j-p	11.53 j-o	44.89 a-f
$V_1C_3D_3$	4.23 r-t	5.58 r-u	9.81 r-u	43.12 b-l
$V_1C_4D_0$	5.93 de	6.72 h-m	12.65 g-j	46.88 a
$V_1C_4D_1$	4.86 j-p	6.07 m-s	10.93 k-r	44.46 a-g
$V_1C_4D_2$	5.35 f-j	6.47 j-o	11.82 j-n	45.93 ab
$V_1C_4D_3$	4.37 q-s	5.66 q-t	10.03 q-t	43.57 a-i
$V_2C_0D_0$	5.95 de	8.10 c-e	14.05 d-f	42.35 c-l
$V_2C_0D_1$	4.58 m-r	6.91 g-k	11.49 j-o	39.87 kl
$V_2C_0D_2$	5.62 e-j	8.15 c-e	13.77 e-g	40.82 i-l
$V_2C_0D_3$	4.30 p-s	6.55 i-n	10.85 m-r	39.63 l
$V_2C_1D_0$	6.30 cd	8.30 b-d	14.60 b-f	43.15 b-l
$V_2C_1D_1$	5.01 h-n	7.25 f-h	12.26 h-k	40.85 h-l
$V_2C_1D_2$	5.97 de	8.28 b-d	14.25 c-f	41.89 e-l
$V_2C_1D_3$	4.53 p-s	6.80 h-l	11.33 j-q	39.98 j-l
$V_2C_2D_0$	6.86 a-c	8.71 a-c	15.57 a-c	44.07 a-i
$V_2C_2D_1$	5.20 g-k	7.21 f-i	12.41 h-j	41.91 e-l
$V_2C_2D_2$	6.32 cd	8.37 a-d	14.69 b-e	42.35 c-l
$V_2C_2D_3$	4.73 k-q	6.82 h-k	11.55 j-o	40.96 g-l
$V_2C_3D_0$	7.17 ab	8.99 a	16.16 a	44.36 a-i
$V_2C_3D_1$	5.49 e-h	7.59 e-g	13.31 f-i	43.53 a-j
$V_2C_3D_2$	6.63 bc	8.69 a-c	15.32 a-d	43.28 b-k
$V_2C_3D_3$	4.91 i-o	6.91 g-k	11.82 j-n	41.53 f-l
$V_2C_4D_0$	7.32 a	8.73 a-c	16.05 a	45.61 a-d
$V_2C_4D_1$	5.78 d-f	7.76 d-f	13.54 e-h	42.69 b-l
$V_2C_4D_2$	6.97 ab	8.90 ab	15.87 ab	43.92 a-i
$V_2C_4D_3$	5.13 g-m	7.03 g-j	12.17 i-m	42.18 d-l
LSD $_{(0.05)}$	**0.28**	**0.34**	**0.68**	**1.79**
CV (%)	**6.73**	**6.10**	**6.90**	**5.07**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Note: V_1 = BARI Gom-28 and V_2 = BARI Gom-30

C_0 = Control (RDCF + no cow dung), C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF + 10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose

D_0 = Control (No stress), D_1 = Water stress at crown root initiation stage, D_2 = Water stress at booting stage and D_3 = Water stress at anthesis stage

4.7.9 Biological yield

Biological yield was significantly influenced by the interaction effect of variety, different levels of cow dung and different water stress of wheat (Table 14). The highest biological yield (16.16 g plant^{-1}) was obtained from the $V_2C_3D_0$ which was statistically similar with $V_2C_4D_0$ (16.05 g plant^{-1}), $V_2C_4D_2$ (15.87 g plant^{-1}), $V_2C_2D_0$ (15.57 g plant^{-1}) and $V_2C_3D_2$ (15.32 g plant^{-1}). On the other hand, the lowest biological yield (8.46 g plant^{-1}) was obtained from the $V_1C_0D_3$ treatment combination which was statistically similar with $V_1C_1D_3$ (9.11 g plant^{-1}), $V_1C_2D_3$ (9.49 g plant^{-1}) and $V_1C_3D_3$ (9.81 g plant^{-1}).

4.7.10 Harvest index

Harvest index was significantly influenced by the interaction effect of variety, different levels of cow dung and different water stress (Table 14). The highest harvest index (46.88%) was obtained from the $V_1C_4D_0$ which was statistically similar with $V_1C_3D_0$ (45.95 %), $V_1C_4D_2$ (45.93 %), $V_1C_2D_2$ (45.86 %), $V_2C_4D_0$ (45.61 %) and $V_1C_2D_0$ (45.38 %) whereas, the lowest ones (39.63%) was obtained from the $V_2C_0D_3$ treatment combination which was statistically similar with $V_2C_1D_3$ (39.98%) and $V_2C_0D_1$ (39.87%).

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted in the net house of the Agronomy department, Sher-e-Bangla Agricultural University, Dhaka 1207 during the period from November 2018 to March 2019 to select the optimum dose of cow dung to mitigate the water stress of wheat. The experiment comprised of three factors viz. factor A: Variety -2; i) V_1 = BARI Gom-28, ii) V_2= BARI Gom-30; factor B: Cow dung doses- 5, i) C_0 = RDCF + Control (Without cow dung), ii) C_1 = RDCF + 25% less cow dung of recommended dose, C_2 = RDCF +10 t ha^{-1} cow dung, C_3 = RDCF + 25% higher cow dung of recommended dose and C_4 = RDCF + 50% higher cow dung of recommended dose; factor C: Comprising water stress by avoiding irrigation- 4; i) D_0 = Control (without water stress), i) D_1 = Water stress at crown root initiation stage, ii) D_2 = At booting stage, iii) D_3 = At anthesis stage. This pot experiment was laid out in a randomized complete block design (RCBD) with three replications. Data were collected on different aspects of yield attributes and yield of wheat.

The result revealed that V_2 (BARI Gom-30) exhibited its superiority to other tested variety BARI Gom-28 in terms of seed yield, the former out-yielded over V_1 (BARI Gom-28) by 21.66% higher yield. V_2 (BARI Gom-30) also showed the highest weight of 1000-grains (46.67 g) and spikelets $spike^{-1}$ (15.01), effective tillers $plant^{-1}$ (4.76), spike length (10.56 cm), straw yield $plant^{-1}$ (7.08 g) and biological yield $plant^{-1}$ (13.55 g) than other tested variety (BARI Gom-28) in this experiment which supports the findings of Mondal (2014). On the other hand, the variety BARI Gom-28 gave 17.80% lower yield which was significantly lower than BARI Gom-30 variety.

Significant differences existed among different doses of cow dung with respect to yield and yield attributing parameters. A yield advantages of 0.24 g, 0.49 g, 0.71 g and 1.03 g $plant^{-1}$ for C_3 (RDCF + 25% higher of 10 t ha^{-1} cow dung), C_2

(RDCF + 10 t ha^{-1} cow dung), C_1 (RDCF + 25% less cow dung of recommended dose) and C_0 (RDCF + without cow dung) applied pot, respectively as found was possibly aided by higher plant height (73.20 cm), tillers $plant^{-1}$ (5.60), spike length (10.82 cm), spikelets $spike^{-1}$ (15.80), grains $spikelet^{-1}$ (1.98), grains $spike^{-1}$ (30.92), weight of 1000-grains (49.19 g), straw yield (7.17 g $plant^{-1}$), biological yield (12.88 g $plant^{-1}$) and harvest index (44.41%) in the C_4 (RDCF + 50% higher cow dung of recommended dose) treatment. On the other hand, treatment C_3 (RDCF + 25% higher cow dung of recommended dose) gave similar result with C_4 treatment in some parameters like—plant height, Spike length, spikelets $spike^{-1}$, weight of 1000-grains, straw yield, biological yield and harvest index.

It was observed that the control plants D_0 (without water stress) out-yielded by producing 7.83%, 24.69% and 38.99% higher yield over D_2 (water stress at booting stage), D_1 (water stress at crown root initiation stage) and D_3 (water stress at anthesis stage), respectively. The treatment D_0 (without water stress) also produced the highest number of tillers $plant^{-1}$ (5.13), longest spike length (10.92 cm), spikelets $spike^{-1}$ (15.60), grains $spikelet^{-1}$ (2.03), grains $spike^{-1}$ (31.07), Weight of 1000-grains (47.79 g), straw yield (7.51 g $plant^{-1}$), biological yield (13.56 g $plant^{-1}$) and harvest index (44.70%) than water stress-imposed plants. However, among the Water stress imposition treatments, D_2 (water stress at booting stage) gave the highest yield (5.62 g $plant^{-1}$) and value for yield attributing parameters than other Water stress imposition treatments.

Interaction of variety and different doses of cow dung significantly influences all the studied parameters including seed yield. The interaction of V_2C_4 produced the highest seed yield (6.30 g $plant^{-1}$) than other interactions except V_2C_3 (6.05 g $plant^{-1}$) which may be attributed to highest effective tillers $plant^{-1}$ (5.96), spike length (11.24 cm), spikelets $spike^{-1}$ (15.84) and weight of 1000-grains (50.58 g) in this interaction. This interaction also showed the highest straw (8.11 g $plant^{-1}$) and biological yield (14.41 g $plant^{-1}$). However, interaction of V_2C_3 showed statistically similar seed yield and some yield attributes like—spike length (10.81 cm), spikelets spike^{-1} (15.53) and weight of 1000-grains (48.85 g) with V_2C_4.

Interaction results of variety and water stress indicated that all the studied parameters were influenced significantly including grain yield. Significantly the highest grain yield (6.72 g plant^{-1}) was found in V_2D_0 (BARI Gom-30 × without Water stress imposition) interaction due to the highest effective tillers plant^{-1} (5.41), spike length (11.32 cm), spikelets spike^{-1} (15.70) and weight of 1000-grains (50.25 g) production. It was also observed that V_2D_2 showed the second highest grain yield (6.30 g plant^{-1}).

Interaction of cow dung and water stress exhibited significant variation in all the studied parameters in this experiment. The interaction C_4D_0 (RDCF + 50% higher cow dung of recommended dose × without water stress treatment) performed the best in respect of grain yield plant^{-1} (6.63 g) which may be attributed to highest effective tillers plant^{-1} (6.43), spike length (11.53 cm), spikelet spike^{-1} (16.55), grains spike^{-1} (36.88) and weight of 1000-grains (52.39 g) in this interaction.

Interaction effects of variety, cow dung and water stress showed significant variation for all the studied parameters. Among the interactions, $V_2C_4D_0$ was superior in producing the highest grain yield (7.32 g plant^{-1}) along with the highest effective tillers plant^{-1} (6.70), spike length (11.86 cm), spikelets spike^{-1} (16.76), weight of 1000-grains (53.20 g), straw yield (8.73 g plant^{-1}) and biological yield (16.05 g plant^{-1}).

Conclusion

From the above result it was revealed that V_2 (BARI Gom-30), C_4 (RDCF + 50% higher of 10 t ha^{-1} cow dung) and no water stress D_0 (without water stress) gave higher yield along with higher values in most of the yield attribute parameters. Among the Water stress imposition treatments, water stress at booting stage (D_2) was high yielder than other Water stress imposition treatments. Among the interactions V_2C_4, V_2D_0 and C_4D_0 were superior in all respect along with grain yield. Interaction of $V_2C_4D_0$ (BARI Gom-30 × RDCF + 50% higher of 10 t ha^{-1} cow dung × without water stress) performed best in all respect including grain yield. The $V_2C_4D_0$ treatment combination also showed better performance in terms of grain yield. From the result of the experiment, it may be concluded that RDCF + 50% higher of 10 t ha^{-1} cow dung seems promising in combating water stress in wheat.

Recommendation

Considering the results of the present experiment, further studies in the following areas are suggested:

1. More cow dung levels may be used for combating water stress/water deficit in different growth stages of wheat.

2. Studies of similar nature could be carried out in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability.

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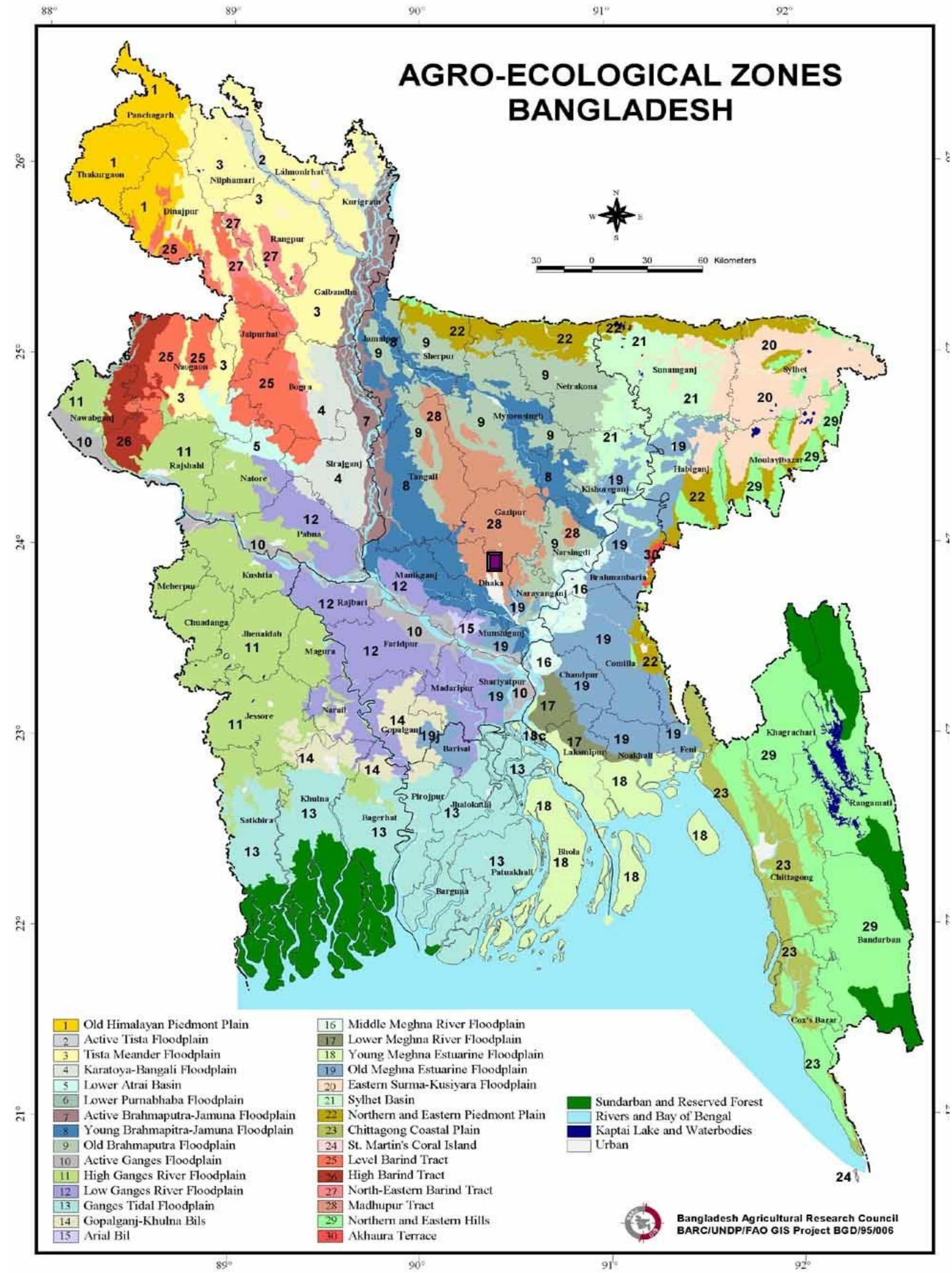
APPENDICES

Appendix I. Experimental location (AEZ 28, Madhupur tract) on the map of Agro-ecological Zones of Bangladesh



■ **The experimental site under study**

Figure 1. The map of Bangladesh showing experimental site

Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0–15 cm depth)

Physical Characteristics:

Constituents	**Percent**
Sand	32
Silt	60
Clay	08
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	1.21
Organic matter (%)	2.08
Total nitrogen (%)	0.104
Phosphorus	60.75 µg/g soil
Sulphur	7.54 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.30 µg/g soil
Copper	1.64 µg/g soil
Zinc	13.72 µg/g soil
Potassium	0.38 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka-1207

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

Months	**Air temperature (°C)**		**Relative humidity (%)**	**Total rainfall (mm)**
	Maximum	**Minimum**		
November, 2018	29.7	19.4	63.25	31.1
December, 2018	16.5	14.8	55.30	12.1
January, 2019	25.1	13.1	50.25	7.5
February, 2019	28.3	16.2	46.17	23.7
March, 2019	32.5	20.8	43.11	61.7
April, 2019	33.8	23.8	40.23	140.23

Source: Bangladesh Meteorological Department (Climate and weather Division), Agargoan, Dhaka- 1207

PLATES

Plate 1. Experimental pots at SAU farm net house

Plate 2. Experimental pots in the net house (Tagged pots)

Plate 3. Supervisor sir with experiment title at the net house

Plate 4. In my experiment plot