INFLUENCE OF CUTTING MANAGEMENT ON GROWTH, GRAIN AND FODDER YIELD OF DIFFERENT CEREALS

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CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF CUTTING MANAGEMENT ON GROWTH, GRAIN AND FODDER YIELD OF DIFFERENT CEREALS**" 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 (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **GULSHAN ARA SHIKHA**, Registration no. **14-05891** 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.

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ABSTRACT

The experiment was conducted at the research field of the department of Agronomy, Sher-e-Bangla Agricultural University during the period from November, 2019 to March, 2020 for assessing cutting management effects on growth and yield performance of different cereals. The experiment comprised of two factors viz. factor A: Cutting (3); i) Uncut - C_1, ii) One cut at 25 Dates After Sowing (DAS) - C_2 and iii) Two cuts at 25 DAS and 61 DAS - C_3; factor B: Crops (4), i) Wheat - G_1, ii) Triticale - G_2, iii) Barley - G_3 and iv) Oat - G_4. This experiment was laid out in a randomized complete block design (RCBD) with three replications. Significant differences were observed among different cutting management with respect to yield and yield attributing parameters of cereal crops. A yield advantages of 0.55 t ha^{-1} and 1.45 t ha^{-1} over C_2 (One cut at 25 DAS) and C_3 (Two cuts at 25 DAS and 61 DAS), respectively was found which was possibly aided by the tallest plant at 80 DAS (105.79 cm), the highest number of tillers m^{-2} (67.54), the maximum number of leaves plant^{-1} at 80 DAS (22.27), maximum leaf area index at 80 DAS (11.06), the highest fresh weight at 80 DAS (101.00 g), highest dry weight at 80 DAS (39.41 g), the maximum number of grains spike^{-1} (54.42), the highest weight of grains spike^{-1} (3.49 g), the longest spike (18.87 cm), the highest straw yield (7.23 t ha^{-1}) and the highest biological yield (12.48 t ha^{-1}) in the C_1 (No cut) treatment. The result revealed that oat (G_4) exhibited its superiority to other tested cereal crop that out-yielded over Triticale (G_2) and Barley (G_3) by 35.59% and 16.00% higher yield, respectively. Oat (G_4) also showed the tallest plant at 80 DAS (107.19 cm), the highest number of tillers m^{-2} (77.25), the maximum number of leaves plant^{-1} at 80 DAS (21.92), maximum leaf area index at 80 DAS (13.86), the highest fresh weight at 80 DAS (90.55 g), the highest dry weight at 80 DAS (34.12 g), the maximum number of grains spike^{-1} (56.66), the lowest number of unfilled grains spike^{-1} (2.35), the highest weight of grains spike^{-1} (3.29 g), the longest spike (26.91 cm), the highest straw yield (10.15 t ha^{-1}) and the highest biological yield (15.75 t ha^{-1}) than other tested cereal crops in this experiment. Among the interactions, C_1G_4 and C_2G_4 were superior in most of the growth, yield attributes and fodder production along with grain yield and yield parameters along with higher amount of fodder production. From the result of the experiment, it may be concluded that oat cut once at 25 DAS seemed promising as dual-purpose crop in Bangladesh.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL WORD
%	Percentage
@	At the rate of
ADF	acid detergent fibre
AEZ	Agro-Ecological Zones
Afr.	African
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
AIS	Agriculture Information Service
Annu.	Annual
ANOVA	Analysis of Variance
Appl.	Applied
Aust.	Australian
BBS	Bangladesh Bureau of Statistics
Biol.	Biology
BLRI	Bangladesh Livestock Research Institute
Bot.	Botany
Ca	Calcium
Chem.	Chemistry
cm	Centi-meter
CV (%)	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
DAT	Days After Transplanting
Dev.	Development
DM content	Dry matter content
DP	Dual purpose
eds.	editors
Environ.	Environmental
et al.	et alia (and others)
etc.	et cetera (and other similar things)
Experim.	Experimental
FAO	Food and Agriculture Organization
Fe	Ferrum (Latin name for Iron)
Forag.	Forage
g	gram
$g \cdot d^{-1}$	gram per day
GDD	Growing Degree Days

LIST OF ABBREVIATIONS AND ACRONYMS

ABBREVIATION	FULL WORD
GS25	Mid-tillering
GS30	stem elongation
GS45	Days to mid booting stage
ha	hectare
HYV	High Yielding Variety
i.e.	id est (that is)
ICARDA	International Centre for Agricultural Research in the Dry Areas
Int.	International
IRRI	International Rice Research Institute
J.	Journal
K	Kalium (Latin name for potassium)
kg	Kilogram (s)
$kg \cdot hL^{-1}$	kilogram per hectolitre
L.	Linnaeus
LAI	Leaf Area Index
LL100%	Entire Leaf from ligule Crash
LL50%	Half of leaf length Clip
LL75%	75% of leaf length Clip
LS50%	Middle of leaf sheath
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
m^{-2}	Per meter squares
mg	Milligram
$MJ \cdot kg^{-1}$	megajoules per kilogram
ml	millilitre
mm	millimetre
MoP	Muriate of Potash
MSTAT-C	Microcomputer Statistical Package-C
NaCl	Sodium Chloride
NDF	neutral detergent fibre
N-free	Nitrogen free
Nutr.	Nutrition
P	Phosphorus
Pak.	Pakistan

LIST OF ABBREVIATIONS

ABBREVIATION	**FULL WORD**
pH	potential of hydrogen
Pharmacog.	Pharmacognosy
Physiol.	Physiological
Phytochem.	Phytochemistry
q ha^{-1}	quintal per hectare
RCBD	Randomized Complete Block Design
RDF	recommended dose of fertilization
Res.	Research
Rev.	Reviews
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter
Technol.	Technology
TSP	Triple Superphosphate
UNDP	United Nations Development Programme
var.	variety
Viz.	*videlicet* (L.), Namely
WDG	Water dispersible granule
Zn	Zinc

CHAPTER I

INTRODUCTION

In Bangladesh economy, agriculture contributes to about 13.02% in GDP and livestock to 3.4% (BBS, 2020). Dairying production is important parts of the rice-based mixed farming systems in Bangladesh and are preferred options for small-scale farmers to generate income and alleviate poverty. Consumers face an acute shortage of milk and meat livestock products, which fail to meet the requirements of over 80% of the population. The per capita daily availability of milk is just 33 ml compared with a requirement of 250 ml, while 10 g of meat is consumed but 120 g is needed. In Bangladesh, most milk is produced by very small-scale farmers with an average of 3.5 cattle per farm household. The shortage of quality fodder and feed is a major constraint for dairy farming in Bangladesh during the lean season from January to May and throughout the year for poultry. Only small amounts of quality fodder and feed are available because of small land holdings (averaging 0.68 ha per household) and multiple attractive crop options during the cool dry (*Rabi*) season from November to March. Rice straw is by far the most important crop residue fed to ruminants in Bangladesh, contributing > 90% of the feed energy available (Saadullah, 2002), but it has relatively low protein quality and energy value. Improved fodder and feed sources have great potential to raise milk production by small-scale dairy farms and enhance livelihoods. The integration of crop and livestock production in the same farming system is a famous strategy of agricultural intensification that is widely recommended, especially in low input systems. However, this mixed agricultural system is often hindered by the seasonal fluctuations in forage supply.

Lack of forage is one of the most important problems of livestock feeding during the winter and early spring and winter cereals provide a very good quality forage for these seasons when they are cut or grazed in suitable vegetative stage (Balabanli *et al.*, 2010; Geren, 2014; Naveed *et al.*, 2014; Kim and Anderson, 2015; Hajighasemi *et al.*, 2016; Munsif *et al.*, 2016). Winter cereals have the ability to regenerate vegetative parts such as stems and leaves after cutting or grazing and they produce grain after this regeneration. For this reason, winter cereals may produce both grain and roughage for livestock in the same growing season with the production system defined as dual-purpose (Royo *et al.*, 1999; Harrison *et al.*, 2012; Hajighasemi *et al.*, 2016; Munsif *et al.*, 2016).

Dual purpose crops are described as varieties (plant genotypes) that can be sown early and are protected from early reproductive development due to the presence of genes that must be triggered by photoperiod (the winter solstice is important) and/or cold (vernalization) (Radcliffe *et al.*, 2012). The practice of grazing winter cereals before the jointing stage and subsequent harvesting of grains is common in some areas of the world (Brown and Almodares, 1976; Dunphy *et al.*, 1982). Among the prominent cereals that proved distinction as dual-purpose crops are barley, oat, triticale, and ryegrass (Salama and Badry, 2021; Salama, 2019; Darapuneni *et al.*, 2016). In the case of dual-purpose utilization of cereals, the determination of the proper age at which forage should be removed is among the most important practices that should be accurately adjusted. In general, removing forage at a later stage of maturity produces a large amount of forage yet negatively affects the crop's regrowth ability, decreasing the final grain production (Singh *et al.*, 2017). Thus, it is crucial to accurately determine the proper age at forage removal in order to achieve a balance between the produced forage on the one hand and the crop's regrowth ability and final grain yield on the other hand (Salama, 2019).

Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereals in the world; some genotypes have the capacity to produce both forage and grain (Szareski *et al.*, 2016; Koch *et al.*, 2017). It contains 79.8% crude fibre, 16.2% of N-free extractives with high dry matter digestibility, and is rich in crude protein (0.4%) and metabolized energy (Dove *et al.*, 2002). Wheat has the potential to meet the food and feed requirements of the rapidly growing human and livestock population from the same piece of land under optimum management practices (Khalil *et al.,* 2011). Wheat can be grown non-traditionally to attain maximum benefit for both grains and feed (Shuja *et al.,* 2010) to diminish fodder shortage during winter. Wheat has the great potential to re-grow and set seed for their dual-purpose cultivation (Francia *et al.*, 2006).

Triticale (× *Triticosecale* W.) is a vigorous wheat-rye cross which produces a high yield of both green biomass and grain throughout the world's cereal-growing regions, particularly on acidic soils. It is good to produce higher biomass and high regrowth after grazing or cutting, and used for its usefulness as a feed grain for livestock animals (Varughese *et al.*, 1997). Triticale performs significantly better than dual-purpose wheat and can produce similar dry matter and grain yields to oats over a winter season (Matthews and McCaffery, 2011). Since the 1970s there has been increased interest in utilization of triticale as a conserved forage or pasture. In the 4th International Triticale Symposium (Red Deer, 1998), 13 of 16 countries indicated that triticale was used for fodder and food and only Spain indicated that triticale was used solely as food. The availability of both winter and spring types has influenced how triticale is used. Triticale is increasingly grown for livestock grazing, whole-plant silage, hay, and forage grain. The majority of triticale varieties have had prominent awns; however increasingly, varieties with reduced awns (Salmon *et al.*, 1996), which make them more suitable for swath grazing and green forage (Baron *et al.*, 2012) are being released.

Barley (*Hordeum vulgare* L.) is a small-grain annual cereal plant with culm up to 70 cm high; leaf-blade 5–16 cm long, 4–8 mm wide and sometimes sparsely hairy. It was one of the most important food crops during the ancient world and is mentioned in the Holy Quran and in the Bible. It is also grown as fodder for animals (Verma *et al.*, 2005). Today its major utility as food crop has reduced but it is still used as fodder crop throughout the world. Barley is mainly cultivated for grain which is consumed as feed and raw material in beverage industries. Barley being a fast-growing crop with high biomass in early stages has been recognized as potential forage resource in arid and semi-arid regions (Srimali, 2008). It can provide nutrition to the animals through its green fodder at vegetative stage and grains after harvest from the regenerated plants.

Oat (*Avena sativa* L.), locally known as "jai" is an important non-legume, cereal forage crop, grown during *rabi* season. It is a palatable, succulent and nutritious crop. The protein quality of oat is excellent. It is rich in energy, protein, vitamin B_1, phosphorous and iron (Tiwana *et al.,* 2008) and is mainly grown in temperate and cool sub-tropical environments. Looking to the chemical composition on dry matter basis, oat at milk stage contains 6.44% crude protein, 28.72% fiber and 53.20% nitrogen free extract. It is a quick growing crop having good regeneration capacity. Its fodder is palatable, succulent and nutritious in two to three cuttings extending from December to February. Oat grain makes a good balanced concentrate in the ration for poultry, cattle, sheep and other animals (Arora, 2014). Due to multicut nature, it helps in making up the fodder deficiency during lean period of forage production and the grains produced can be used as concentrate, which is nutritive and economical as compared to other commonly used concentrates.

Cereal crops have potential to produce more grain yield along with substantially higher green fodder and also for enhancing net income. Dual purpose crop requires high level of management. Schedules of cutting is important to realize the optimum yield of green fodder and grains from dual purpose cereal. Keeping these points in view, the present investigation was taken up to attain the following objectives:

1. To explore grain and fodder production from different cereal crops as dual purpose.
2. To investigate the effect of cutting time on grain yield and fodder production.

CHAPTER II

REVIEW OF LITERATURE

Research works are very limited regarding influence of cutting management on different cereal crops for assessing their role as dual purpose crop in Bangladesh. It is an attempt to find out the performance of wheat, triticale, barley and oat under different cutting management practices in relation to dual-purpose. To facilitate the research work, different literatures from abroad have been reviewed in this chapter under the following headings:

2.1 Effect of cutting management on wheat

Munsif *et al.* (2020) explored the potential of wheat as a dual-purpose (DP) crop for improving both, forage and grain cropping system by finding out optimal sowing dates and cultivars suitable for DP cropping. Field experiments with four cultivars (Saleem-2000, Bathoor-2007, Fakhre Sarhad-99 (FS-99) and Siran-2008), three sowing dates (October 15, October 30 and November 15) and two cutting treatments (cut and no-cut) determined the effects on yield and physiology of wheat. Biological and grain yields were reduced by 4% and 3%, respectively under the DP wheat compared with no-cut treatment, but grains N content was unaffected. Conclusively, DP wheat system (cut treatment) had higher profitability (11.20%) than wheat crop sown only for grain purposes.

Carvalho *et al.* (2019) evaluated the effects on the nutritional value of the forage of five genotypes of wheat with dual purpose submitted to different sowing densities, as well as different cutting managements. The experiments were carried out with five genotypes of dual-purpose wheat (BRS Tarumã, BRS Umbu, BRS Figueira, BRS Guatambu and BRS 277) × five sowing densities (75, 150, 225, 300 and 375 seeds per square meter) × three cutting managements (one, two and three cuttings). The attributes of interest were obtained through the collection of all plants per experimental unit. These included percentage of crude protein, lipids, neutral detergent fibre and non-fibrous carbohydrates. The bromatological quality of forage from wheat with dual purpose depended on cutting management, genotype and sowing density. The maximum protein fraction and non-fibrous carbohydrates in the forage was obtained at intermediate sowing densities of 300 and 375 seeds·m^{-2}, independent of the genotype for the largest number of cuttings.

Hu *et al.* (2019) established two experiments to measure yield and its components, evapotranspiration, water-use efficiency (yield per unit evapotranspiration), accumulation and apparent remobilisation of stem water soluble carbohydrates (WSC), and economic benefit of dual-purpose winter wheat. Experiment 1 combined factorially three defoliation treatments, i.e. winter defoliation (DC23), spring defoliation (DC29) and untreated control, two seeding rates (currently recommended, and 125% recommended), and over four seasons. Experiment 2 combined factorially two defoliation treatments (spring defoliation and control), two nitrogen rates (low: 120–150 kg N·ha^{-1}, high: 180–200 kg N·ha^{-1}), three levels of soil water at sowing (low: rainfed; medium: rain + 67 mm; high: rain + 133 mm), and over three seasons. Defoliation was largely neutral for grain yield and water-use efficiency, and improved translocation of WSC to grain by 8%, harvest index by 7% and net income by 15% across conditions. Grain yield was unaffected by the interaction between defoliation and seeding rate, but significantly impacted by interactions of defoliation × initial soil water level and defoliation × nitrogen rate. Defoliated wheat yield was greater at high than at medium and low initial soil water content, and at low than at high nitrogen rate. Spring defoliation produced similar yield as winter defoliation but the former increased forage income. Thus, dual-purpose winter wheat was more profitable (i) when defoliated in spring, (ii) at the lower seeding density, (iii) under the lower nitrogen rate, and (iv) with higher soil water content at sowing. Apparent translocation of stem WSC partially mediated the effect of defoliation on grain yield. It was concluded that dual-purpose winter wheat was feasible under straw mulching in semiarid environment.

Atis and Akar (2018) investigated the effects of sowing date and cutting heights on grain yield, forage yield and nutritive value of dual-purpose wheat during two consecutive growing seasons (2013–14 and 2014–15). The experimental design was split-plot under randomized complete block design, sowing dates (early, normal and late) as the main plot treatments and cutting heights (5, 7.5 and 10 cm) as the subplot treatments with three replications. Deeper cutting increased forage yield, while decreased grain yield. The effects of cutting heights on forage quality were different between years. The cutting treatments caused the decrease yield of the grain, but dual-purpose system for winter wheat was an advantageous crop system when evaluated in terms of the total amount of production. The height of 7.5 cm can be recommended as a suitable cutting height in term of the total crop quantity.

Dhaka *et al.* (2018) conducted a field experiment having four sowing times in main plots and five cutting schedules in sub plots to find out the effect of growth and yield of dual-purpose wheat. Among cutting schedules, higher rate of reduction was recorded with delay in cutting of fodder from 45 DAS up to 75 DAS. For dual purpose, tall wheat (C306) sown during 3rd week of October and harvested at 55 DAS for fodder purpose was found most suitable having green fodder yield (14,313 kg ha^{-1} additional over uncut), grain yield (3,710 kg ha^{-1}, with a reduction of 9.30% over uncut), straw yield (7,820 kg ha^{-1} with a reduction of 19.70 % over uncut).

Iqbal *et al.* (2018) conducted a study to estimate reduction in weeds density in dual purpose wheat crop utilized for forage and grain production under different cutting stages. Wheat variety Atta-Habib was sown for fodder and grain production. The five treatments were consisting of no-cut and one cut i.e. at Zadok growth stage 12 or 14 or 16 or 18. Results showed that fodder production was increased while weeds fresh and dry weight were reduced with delaying cutting stage from ZGS-12 to ZGS-18, whereas biological and grain yield were also decreased from 13354 to 9949 kg ha^{-1} and from 4552 to 3086 kg ha^{-1} respectively with delayed cutting. No cut results highest weeds density (241 m^{-2})

as compared to cut at ZGS 18 i.e. (131 m^{-2}). From all findings it was concluded that no cut is optimum to obtain higher grain yield (4542 kg ha^{-1}) and highest biological yield (13354 kg ha^{-1}) but cut at ZGS-18 is optimum for forage production (1865 kg ha^{-1}) as well as for reduction in yield losses due to weeds. About 48% weeds control and the highest green fodder may be obtained with a reduction of 1466 kg ha^{-1} in grain yield and 3405 kg ha^{-1} in biological yield.

Waheddullah *et al.* (2018) conducted a field experiment to study the influence of sowing times and cutting schedules on quality and economics of dual-purpose wheat. The experiment was comprised of four sowing times (3rd week of October, 4th week of October, 1st week of November and 2nd week of November) as main plot treatments and five cutting schedules (Uncut, cutting at 45 DAS, cutting at 55 DAS, cutting at 65 DAS and cutting at 75 DAS) as sub plot treatments. Tall wheat variety C306 was sown. Cutting of wheat for fodder purpose had reduced significantly all quality parameters and yield compared to uncut. Among the cutting schedules, compared to uncut wheat maximum and minimum percent reduction in quality parameters and yield was recorded with cutting of wheat for fodder at 75 DAS and 45 DAS, respectively. With the delay in cutting of wheat for fodder purpose from 45 to 75 DAS, the percent reduction range of 4.4–11.5 (protein content in grain), 0.80–2.60 (hectoliter weight), 14.70–24.40 (grain appearance score) and 2.10–36.0 (grain yield) was recorded compared to uncut wheat, but an additional green fodder yield of 5625–29233 kg ha^{-1} was obtained with delay the fodder cutting time from 45 to 75 DAS. The reason of reduction in hectoliter and grain appearance score due to late cutting of wheat might be removal of photosynthetic organs by clipping, which negatively affected source sink relationship. Among the cutting schedules, early cutting (45 DAS) was recorded with significantly higher grain yield (4,005 kg ha^{-1}) and straw yield (7,195 kg ha^{-1}) while late cutting (75 DAS) resulted with minimum grain yield (2,618 kg ha^{-1}) and straw yield (3,665 kg ha^{-1}) and the reasons of significant reduction of yield in cut plots was possibly due to removal of photosynthetic tissues that resulted in lower crop growth rate, grain weight and number of productive tillers and the reverse was true for no-cut treatment. Cutting of wheat at 45 DAS was recorded with maximum value of all quality parameters and yield, while cutting at 55 DAS was found most profitable.

Zeb (2018) conducted three experiments in a glasshouse to study the relationship between defoliation, plant morphology and crop recovery for understanding about wheat defoliation management and identification of potential varieties for Tasmania. In first experiment, four wheat varieties (Tenant, Revenue, Chara and Bolac) were defoliated using Clip and Crash strategies at four different plant anatomical cut points (LL75%, LL50%, LL100% and LS50%) at mid-tillering (GS25). Clipping at 50% and 75% of leaf length had positive effects on regrowth and increased crop height by 15%. Crash treatments were cut at the end or half way along the leaf sheath and produced more forage but affected plant regrowth at the start of stem elongation (GS30). A second experiment was established in a field to study the effect of cutting height on forage yield and crop regrowth of three wheat varieties (Bolac, Revenue and CS170). Five cutting heights were imposed at mid-tillering (GS25) to estimate forage yield. Treatments included Clipping (cutting at ground level, 3 and 5 cm) and Crash (cutting at 8 and 10 cm above ground level). Clipping treatments did not affect plant height or biomass compared with the uncut control whereas the Crash treatment significantly affected plant height at the start of stem elongation (GS30). Moreover, forage production at mid-tillering (GS25) was significantly influenced by cutting. The Biomass yield of Clipped plot was 50% less than control, whereas, defoliating above 5 cm resulted plant height similar to uncut. Tall and medium statured varieties produced 50% more forage yield than prostrate. Defoliation below 5 cm affected plant regrowth and biomass. The findings from both experiments above were applied in experiment 3 to evaluate 99 genotypes including landraces and commercial from China and Australia to identify the new varieties suitable for DP production under Tasmanian conditions. Evaluation of two levels of cutting treatments (control and cut at 5 cm) at the start of stem elongation (GS30) showed differences among genotypes in calendar days, forage yield, plant height and GDD (Growing Degree Days). Genotype H-051 had the greatest height (46.6 cm), higher forage yield (2.23 t ha^{-1}) and biomass yield (3.39 t ha^{-1}). Genotypes H-061 and Mackellar showed the best potential regrowth capacity by attaining height (60 and 64 cm respectively) after cutting at GS30. The genotypes accumulating less days to reach GS45 had less height than genotypes accumulating maximum GDD to GS45. The regrowth of the genotypes after defoliation was related to the number of leaves on main stem and tillers plant ha^{-1}. The genotypes reaching stem elongation stage late had higher forage and biomass yield. The genotypes producing higher forage yield and recovering height similar to uncut were recommended to be evaluated at other location across Tasmania for further screening.

Martin *et al.* (2011) evaluated the effect of nitrogen fertilization and aerial part cuts on yield components, grain yield and quality of the grains for dual-purpose wheat cultivars. The main causes of variation were dual-purpose wheat cultivars (BRS Figueira, BRS Umbu, BRS Guatambu and BRS Tarumã), nitrogen doses (0, 45, 90, 135 and 180 kg ha^{-1}) and cut systems. Each plot was subdivided by cut management (without cut, one cut and two cuts). Spike mass, number of spikelets·spike^{-1}, number of grains·spikelet^{-1}, grain yield and hectoliter weight were evaluated. Nitrogen fertilization did not affect the performance of wheat genotypes, but there was interaction between the management systems and the cultivars. The shorter-cycle cultivars (Figueira and Umbu) presented greater grain yield than the others when they were not cut. As quality and yield fell when Figueira and Umbu were cut, the later cultivars (Tarumã and Guatambu) were more adapted to cut (grazing).

Bisht *et al.* (2008) studied the influence of wheat variation and their cutting schedule on fodder and grain yield. Selected wheat varieties included VL *Gehun* 829, VL *Gehun* 616 and advance lines of VL 818 and VL 840, respectively. Significantly higher green fodder yield (69.32 q ha^{-1}) was obtained from VL 818 than under VL *Gehun* 616 and VL *Gehun* 829, while it was at per with fodder yield of VL 840. Cutting of green fodder scheduled at 70 DAS and 85 DAS resulted no significant difference in yield. However, it showed the possibility of extended availability of green fodder without affecting the production the grain and straw yield obtained under VL *Gehun* 829 (60.05 q ha^{-1} and 121.5 q ha^{-1}, respectively) were statistically superior to VL *Gehun* 616 and VL 818 and at par with VL 840. Harvest of green fodder affected grain yield of wheat up to 7% through it was not statistically significant. Therefore, it was concluded that among the different cultivar VL *Gehun* 829 and VL 840 are the most suitable for dual purpose and can be cut after 70 DAS and 85 DAS for green fodder as both stage of cut produced at par green fodder, grain and straw yields, thereby ensuring fodder and food security in the region.

Arif *et al.* (2006) worked on the dual-purpose wheat and found that non-cut plots produced significantly more spikes, grains $spike^{-1}$, grain weight, grain yield and biological yield.

Arzadún *et al.* (2006) set up a field trial to observe the effect of planting date, clipping height and cultivar on forage and grain yield of winter wheat in Argentinean Pampas. The researchers observed that in winter wheat at 3-cm clipping height yielded 21% more forage than clipping at 7 cm height.

2.2 Effect of cutting management on triticale

Rajae *et al.* (2017) carried out a research work to identify productive and suitable triticale material intended for dual purpose use under Moroccan climate and soil conditions. 50 advanced accessions of hexaploid triticale were tested for vigor, earliness, biomass and grain yields. Selected accessions were compared to barley, rye and triticale cultivars for forage and grain productions. Field trials were conducted with varying defoliation regimes (uncut to grain yield, cut at erect leaf stage and cut prior to last leaf emergence). Yielded dry matter ranged between 0.96 and 2.74 $t \cdot ha^{-1}$ respectively for early and delayed cutting. Four accessions yielded high forage such as barley, rye and triticale cultivar Juanillo. Forage removal had a depressive effect on grain yield for which losses reached

11% for early clipped genotypes and were of 32% to 73% when accessions were defoliated later. Grain and straw yield losses reported to forage harvested at vegetative stage indicated that genotypes E12, E18, E19, E20, Juanillo and barley cultivars gave the best compromises and were the most adapted to clipping.

Dennett and Trethowan (2013) compared the yield, test weight, ash and protein content of four winter triticale genotypes in replicated grain only and dual-purpose treatments over five year-site environments, based on a previously reported hypothesis that removal of triticale biomass reduces grain ash content. They reported that triticale is a high yielding cereal grain which performs well as a dual-purpose crop (both midseason biomass and end-season grain harvests), however, is usually inferior to wheat under the requirements of a high-value milling grain market. There is potential to increase the profitability of dual-purpose triticale by improving grain quality for food products. Currently the ash content of triticale grain is above acceptable limits and protein content is usually below the requirement for a milling market. Cutting had a highly variable influence on yield and protein content between genotypes. Ash content was either unaffected or increased by cutting, again depending on the genotype. Ash content was negatively correlated with both stage of plant development when cut (explaining 82% of the variation) and amount of dry matter removed (explaining 65% of the variation). The results suggested that ash content in dual-purpose triticale grain may be reduced by combining suitable cultivars with later cutting; however, this may also decrease the grain protein content. It is unlikely that grazing or cutting is a suitable strategy to reduce ash content in triticale to the level required by wheat milling markets.

Gim *et al.* (2008) reviewed the situation of Triticale cultivation and examined the potentiality of contribution to livestock as well as poultry sector in Bangladesh agriculture. Triticale is a human-made cross between rye and durum wheat that has the ability to produce quality green fodder, and then re-grow after first and second cutting to produce grain. In Bangladesh, it is a non-traditional cereal that grows well during the cool and dry Rabi season (November –March) when fodder and feed scarcity is a major limiting factor for ruminant livestock. In Bangladesh Triticale was started to grow in the late Ninety's. The scientists of Bangladesh Agricultural Research Institute (BARI) were first introduced triticale in Bangladesh. Still now the situation of Triticale is grown as fodder and feed in Bangladesh within the scientists under trial. High quality grass fodder was obtained by cutting green triticale plants twice, at 35 and 50 days after seeding, while later the ratooning tillers produced grain to a yield of 1.10–2.40 $t \cdot ha^{-1}$ of grain for poultry feed or human food. Triticale straw was twice as nutritious as rice or wheat straw and its grain contained more protein than other cereals. Researchers and farmers have also successfully made triticale hay and silage from a mixture of triticale green cuttings, rice straw and molasses. A feeding trial at Bangladesh Livestock Research Institute (BLRI), Savar station showed a large increase (46%) in cow live weight gain and a 36% increase in milk yield (but no change in milk quality or dry matter intake) in cows fed triticale silage compared with those fed rice straws over a period of nine weeks. In another feeding trial, it was found that triticale grain was a good replacement for wheat in the feed blend for chickens in Bangladesh. So, it will be a good chance to alive our livestock as well as poultry sector if triticale enters to our existing cropping system as fodder cum grain. The challenge in Bangladesh is to identify fodder technologies that match existing small-scale farmer cropping patterns without needing major inputs or increasing risks. Preliminary field experiments revealed that triticale is a crop with good potential to produce quality fodder and grain for small scale farmers in Bangladesh.

Haque *et al.* (2006) reported that in Bangladesh, fodder and feed scarcity is a major limiting factor from January to May for ruminant livestock and throughout the year for poultry. During 1999–2002, triticale was assessed as a dual-purpose crop to meet needs for quality fodder and grain during the lean season. High quality grass fodder was obtained by cutting green triticale plants twice, at 35 and 50 days after seeding, while later the ratooning tillers produced grain. Fiftyfour on farm demonstrations conducted throughout Bangladesh in 2001–02 showed that 6–15 $t \cdot ha^{-1}$ of fresh mass fodder can be produced from two cuts within 50 days. Triticale crops can then grow on to yield 1.10–2.40 $t \cdot ha^{-1}$ of grain for poultry feed or human food. Tests in Bangladesh have shown triticale fodder quality to be similar to several forage legumes and well above grass forages, with 24.7% crude protein in the dry matter and metabolizable energy values of 10.60 $MJ \cdot kg^{-1}$ dry matter. Triticale straw was twice as nutritious as rice or wheat straw and its grain contained more protein than other cereals.

Agyare *et al.* (1996), Miller *et al.* (1993) and Poysa (1985) from their individual research work on triticale reported that generally, more frequent and later clipping results in greater forage yield, but also greater reductions in grain yield of triticale. Agyare *et al.* (1996) and Miller *et al.* (1993) also mentioned that in case of triticale, varieties differ in their response to time of cutting or grazing on grain and forage yields.

Royo *et al.* (1996) reported that winter triticale breeding lines grown in a Spanish Mediterranean climate were found to yield 1.4 times more forage than spring types, although they suffered greater grain loss due to clipping.

Garcia Del Moral *et al.* (1995) determined the effect of two seeding dates and three cutting frequencies on forage production, grain yield, forage and grain protein content, and several associated characteristics of Triticale (× *Triticosecale* Witt.) in 1990 and 1991 at three field locations in southern Spain. Seeding date was less influential on forage and grain production than cutting treatments. Forage harvest significantly reduced grain yield 19.10% to 54.70% with one cutting and 46.60% to 76.20% with two cuttings. Plant height was reduced 5.60% to 18.80% with one cutting and 16.40% to 43.30% with two cuttings. Grain protein yield was reduced 18.60% to 53.70% with one cutting and 47.90% to 72.8% with two cuttings. Grain protein content increased 5.60% to 23.30% with one cutting and 8.0% to 32.0% with two cuttings at the rainfed sites, but not under irrigated conditions. Forage protein content was negatively related to forage yield both in rainfed (r = −0.824) and irrigated (r = −0.952) environments, probably due to a dilution effect. An inverse linear relationship was found between grain yield and protein content (r = −0.901) in the four rainfed experiments, probably from differences in accumulation of starch. Under irrigated conditions and high soil fertility, cuttings did not affect the final percentage of protein in the grain, although grain yield decreased. An inverse relationship was found between the rainfall measured during the triticale growing season and the mean protein content in the grain (r = −0.911) under rainfed conditions.

Poysa (1985) carried out an experiment to study the effect of forage harvest on grain yield and agronomic performance of winter triticale, wheat and rye. The researcher reported that clipping early resulted in less lodging and enhanced grain yield in winter triticale.

2.3 Effect of cutting management on barley

Salama (2019) conducted a two-year field study to explore the variations in forage and grain yields and their characteristics of barley seeded with 100, 125, and 150 kg ha^{-1} and cut at 45, 55, and 65 days after sowing (DAS). Cutting barley at early growth stages (45 DAS and 55 DAS) resulted in the production of higher forage yield with higher quality, in terms of high crude protein and low fibre content, compared to late forage cut at 65 DAS. Meanwhile, early forage cutting resulted in the least amount of reduction in the final grain yield and, thus, grain income. The percentage reduction in grain income associated with forage cutting at 45, 55, and 65 DAS, amounted to 5.70%, 19.60% and 31.00%, respectively. However, the net returns obtained from the dual-purpose system, when forage was cut at 45 and 55 DAS were $104.27 (11.4%), and $67.91 (7.4%), respectively, greater than that obtained in the grain-only system. Economic analysis showed that the extra income from early forage cutting was sufficient to compensate the grain yield reduction in the dual-purpose system. Dual purpose barley production, thus, proved to be highly feasible in the region due to the good price of the barley forage.

Verma (2019) carried out field trials to identify the barley genotypes with higher green forage yield at cut with minimum impact on the grain and straw yields of the regenerated crop. The cut for green forage was taken at 55 days after sowing. There was significant effect observed on traits like plant height, spikes·m^{-2} for cut treatment over no-cut, while spike length and grains $spike^{-1}$ were not affected much.

Meena *et al.* (2017) conducted a field experiment to study the performance of dual-purpose varieties, cutting schedules and fertility levels to growth and productivity of barley (*Hordium vulgare* L.). The experiment consisted combinations of two dual purpose barley varieties (RD 2715 and RD 2552), three cutting schedules (40 DAS, 50 DAS and 60 DAS) and three fertility levels (RDF: 60 kg N + 20 kg P_2O_5 ha^{-1}, RDF + 25% extra N and RDF + 50% extra N). Dual purpose barley varieties were not significantly influenced on day to 50% heading and maturity of crop after green fodder cutting. Variety RD 2552 recorded significantly higher grain, straw and biological yield over RD 2715. The results revealed that various cutting schedule failed to record perceptible variation on plant height, number of total tillers, dry matter and LAI at 35 DAS. But cutting of barley for green fodder at 60 DAS produced the maximum plant height, number of total tillers, dry matter and LAI as compare to 40 and 50 DAS. In general, overall improvement in growth of green fodder could be ascribed to favourable internal environment of the plants as well as external environment (atmospheric conditions) to which it was exposed during its life cycle. Later at 15, 30, 45 days after green fodder cutting and at harvest, plant height and dry matter increased under cutting of forage at 40 DAS over 50 and 60 DAS. Days to 50% heading was recorded significantly increased under cutting of green fodder at 40 DAS, but days to maturity was obtained the highest at 60 DAS could be due to the availability of favourable environmental conditions (external and internal) led to better growth of each components and available for each plant which dictated the availability of various growth inputs to individual plants in the community and also the extent of competition between and within plant for various growth inputs. It is an establish fact that the growth of crop is outcome of genomic and environment interaction. The grain, straw and biological yield were significantly higher when cutting was done at 40 DAS for green fodder but maximum green fodder yield was produced at 60 DAS. This may be due to the more yield attributes and growth with earlier cutting of green fodder. Green fodder cutting at 60 DAS produced highest green fodder yield (29.80 t·ha^{-1}), as compare to 40 DAS and 50 DAS, while grain (4.10 t·ha^{-1}), straw (7.09 t·ha^{-1}) and biological yield (11.19 t·ha^{-1}), produced significantly higher at 40 DAS over 50 DAS and 60 DAS green fodder cutting.

Singh *et al.* (2017) reported that cutting at early stage at about 50–55 days after sowing, provides good quality of fodder particularly in lean period (mid-December to mid-January) for feeding to the animals. After harvesting for fodder, the regenerated crop left for grain production without sacrificing the grain yield with similar management as grain crop. For dual purpose barley need to evaluate the cultivars, optimum sowing time and stage of harvesting is a critical issue for production of good quality fodder as well as grain. It was found that optimum sowing time for dual purpose barley was mid of October to mid of November. Delayed sowing decreased in fodder as well as in yield attributing characters and grain yield and quality of fodder. It was noticed that at one cutting (50–55 DAS) a suitable stage of harvesting for green forage as well as grain crop obtained from regenerated dual-purpose barley crop.

Kaur *et al.* (2013) reported that forage cut of barley at 60 DAS produced significantly higher dry fodder yield (24.2 q ha^{-1}) than the forage cut at 45 DAS (11.1 q ha^{-1}) and this gave 119% higher dry fodder than the forage cut at 45 DAS. They also reported that barley forage cut at 45 DAS had significantly higher content of crude protein (13.3%), ether extract (2.87%), mineral matter (12.0%) and dry matter digestibility (79.94%) but forage cut at 60 DAS had significantly higher content of crude fibre (26.5%) and nitrogen free extract (52.86%) than forage cut at 45 DAS. Barley forage cut at 60 DAS had produced significantly higher yield of crude protein (24.2 q ha^{-1}), crude fibre (2.10 q ha^{-1}), ether extract (6.4 q ha^{-1}), mineral matter (0.62 q ha^{-1}), nitrogen free extract (2.31 q ha^{-1}) and digestible dry matter (0.62 q ha^{-1}) than forage cut at 45 DAS.

Kharub *et al.* (2013) stated that barley for green forage and grain can be grown in semi-arid and arid climatic conditions where no other green forage is available in winter months due to shortage of irrigation water or insufficient rains. New varieties have been developed zone wise for dual purpose barley and their performance has been evaluated in this study. Different varieties were screened for dual purpose barley by taking multilocation experiments. In one experiment, different varieties were grown and green forage was taken at 40, 55 and 70 days after sowing to optimize the date of cutting for green forage. For dual purpose barley crop, the stage for forage cutting is the most important on which both forage and grain yield depends. If cut is given early, forage yield will be reduced and if cut is given slight late, plant regeneration and the grain yield will be affected. Multi-location experiment results have shown that the crop can be given one cut at about 55 days after sowing for green forage in plains and the regenerated crop can be utilized for grain purpose which gives satisfactory levels of grain yield. At this stage, the reduction in grain yield over cut at 40 days was around 25% but significant gain in forage yield was observed. Similarly increase in forage yield was not enough to compensate the yield reduction at 70 days cut over cut at 55 days (Kharub *et al.*, 2007). Therefore, cut at 55 days after sowing was found optimum in Northern plains and central zone. In case of Northern Hills, coordinated experiments conducted under rainfed conditions indicated that the optimum stage of cutting is around 70–75 days after sowing. Irrigation immediately after forage cut is required for better rejuvenation. The results of different experiments revealed that barley can produce up to 172 quintals of green forage ha^{-1} and after rejuvenation can produce 41 quintals of grain yield. Berseem, oats and sugarcane needs more irrigation and inputs as compared to barley and cannot be grown where water is scarce. The study has clearly shown that dual purpose (forage and feed) barley crop is significantly beneficial as compared to barley grown for feed purpose only in dry areas where green forage is a scarce commodity. Barley grown with senji or mustard was equivalent with barley alone in producing green fodder and grain. Dual purpose barley provides nutrition rich green fodder for the livestock at the time of scarcity and at the same time also provides acceptable quality grain for human consumption. On an average, 180–240 q ha^{-1} and 24–35 q ha^{-1} of green fodder and grains, respectively were produced from dual purpose barley.

Jain and Nagar (2010) reported that barley crop cut at 45 days after sowing yielded the highest grain yield (28.7 q ha^{-1}). It was numerically low (3.75%) in no-cut crop and reduced significantly by 20.1% in 55 days cut crop.

Pal and Kumar (2009) carried out an experiment for evaluation of dual-purpose barley for fodder and grain under different cutting schedules. The researchers observed the highest grain yield of barley in no-cut crop.

Kharub *et al.* (2007) reported that at 55 days stage, the reduction in grain yield of barley over cut at 40 days was around 25% but significant gain in forage yield was observed. Similarly increase in forage yield of barley was not enough to compensate the yield reduction at 70 days cut over cut at 55 days.

Boss and Carlson (2001) showed that earlier cutting of barley appeared to be of higher forage quality than late cutting.

Abdullah *et al.* (2000) reported that barley cutting for forage at the age of 65 days was superior (5.17 $t \cdot ha^{-1}$) to cutting at the age of 50 days (2.10 $t \cdot ha^{-1}$). Utilization of vegetative growth for forage at the age of 65 days has resulted in a reduced barley grain yield ranging from 12% and 59% in the first and the third planting dates respectively. Whereas the reduction in straw yield was greater ranging from 35% to 58% in the first and the third planting dates respectively.

Yau *et al.* (1989) carried out an experiment to study the effects of green-stage grazing on rainfed barley in northern Syria. The researchers reported from their experimental work that single grazing at the tillering stage reduced both grain and straw yield of barley.

2.4 Effect of cutting management on oat

Pravalika and Gaikwad (2021) performed a field experiment for studying the effect of different levels of nitrogen application and cutting management on yield, quality and economics of fodder oats (*Avena sativa* L.). The treatment combinations include five nitrogen levels, i.e., 0, 60, 90, 120 and 150 kg N ha^{-1} and two cutting managements i.e., C_1 (Single cut at 50% flowering stage), C_2 (First cut at 60 DAS and second cut at 50% flowering). The oat variety Kent seed was used in the sowing. The results of research work on revealed that regarding to cutting management, the highest plant height (96.31 cm), number of tillers (67.72), leaf : stem ratio (1.11) were found maximum at C_1 and green fodder yield (655.12 q ha^{-1}), dry matter yield (102.25 q ha^{-1}), crude protein yield (10.82 q ha^{-1}) and crude fibre yield (21.26 q ha^{-1}) were found the maximum under C_2. The highest gross realization, net realization and benefit cost ratio were received under C_2.

Arif *et al.* (2019) conducted a field experiment during rabi seasons of 2016–17 and 2017–18 to study the effect of sowing time (25th October and 25th November), cutting schedules (cut at 50 DAS, cut at 60 DAS and cut at 70 DAS) and nitrogen levels (80, 100 and 120 kg ha^{-1}) on productivity and quality of fodder oats. Among different cutting schedules, cutting at 70 DAS recorded significantly higher green (37.8 t ha^{-1}) and dry (8.3 t ha^{-1}) fodder yield. However, cut at 50 DAS proved significantly better in terms of green (628.7 kg ha^{-1} day^{-1}) and dry (137.0 kg ha^{-1} day^{-1}) fodder production efficiency as well as quality parameters *viz.* crude protein (12.30%) and ether extract (2.56%).

Rahate *et al.* (2019) carried out an agronomic investigation on oat cv. RO-19 (Phule harita) to study the growth and productivity dynamics of fodder oat as influenced by silicon and cutting management. The treatments comprising of four silicon levels *viz.* 0, 200, 300 and 400 kg Si ha^{-1} and three cutting *viz.* no cut, cutting at 45 DAS and 55 DAS. Among the cutting management, no cut treatment was recorded with the highest plant height, dry matter accumulation $plant^{-1}$, seed yield and straw yield, while cut at 55 DAS produced significantly higher number of tillers at harvest, green forage yield, Gross Monetary Returns, Net Monetary Returns and Benefit : Cost ratio.

Sheoran *et al.* (2018) conducted the field experiment with the objective to study the effect of cutting management and phosphorus fertilization on forage and seed production of multicut oat. Treatment combinations comprised of eight cutting management treatments i.e. C_1 (Seed to Seed), C_2 (Fodder at 50% flowering), C_3 (Fodder 60 DAS- Seed), C_4 (Fodder 70 DAS- Seed), C_5 (Fodder at 80 DAS-Seed), C_6 (Fodder 60 DAS- Fodder at 50% flowering), C_7 (Fodder at 70 DAS-Fodder at 50% flowering), C_8 (Fodder 80 DAS- Fodder at 50% flowering) and four levels of phosphorus i.e. 0, 20, 40 and 60 kg P_2O_5 ha^{-1}. The results indicated that the highest green fodder and dry matter yield was obtained when only one cut of fodder was taken at 50% flowering stage and it was statistically at par for green fodder yield with treatment where first cut for fodder was taken at 80 DAS and second cut at 50% flowering stage. Harvesting of fodder at 80 DAS gave significantly higher forage yield and seed yield than the harvesting at 60 or 70 DAS. Contrary to this, the straw yield and biological yield were significantly higher in the treatment when the crop was raised purely for seed purpose. Under dual system, delay in first cut i.e. from 60 to 80 DAS resulted in a significant increase in fodder and seed yield over the earlier cuttings.

Malik and Babli (2017) carried out a field experiment to observe the effect of various cutting management schedule in oat crop. Oat var. HJ 8 was taken as test crop. Three cuttings (C_{50} = first cut 50 DAS, C_{60} = second cut 60 DAS and C_{70} = third cut 70 DAS) were maintained. Results obtained from the field experiment on oat crop indicated that the highest fodder yield was recorded when crop was cut at 70 days after sowing (DAS) followed by cut at 60 DAS and the least by 50 DAS. The highest grain yield was recorded when oat was cut at 60 DAS (28.06 q ha^{-1}) followed by cut at 50 DAS (25.57 q ha^{-1}) and the lowest by cut at 70 DAS (23.93 q ha^{-1}). However, straw yield was recorded the maximum under treatment cut at 50 DAS (65.46 q ha^{-1}) followed by at 60 DAS (63. 68 q ha^{-1}) and the least at 70 DAS (55. 40 q ha^{-1}). Crude protein in fodder decreased significantly with increase in age of crop and decrease was from 13.51% at cut at 50 DAS to 12.64%, 12.51% at cut 60 DAS and 11.77% at cut at 70 DAS. Maximum plant height was recorded when oat was cut at 70 DAS (65.9 cm) followed by cut at 60 DAS (53.8 cm) and then cut at 50 DAS (45.9 cm). The highest green fodder and dry matter accumulation were recorded when oat was cut at 70 DAS (172.6 q ha^{-1} and 34.4 q ha^{-1}) and the least when oat was cut at 50 DAS (140.2 q ha^{-1} and 22.8 q ha^{-1}). Seeds·panicle^{-1} were found the highest (66.0) under first cut and the lowest at third cut for fodder (62.20 grains panicle^{-1}). The test weight of oat was found the highest (39.23 g) at 60 DAS and it was significantly higher over 50 DAS and 70 DAS.

Sharma *et al.* (2017) conducted a field experiment to study the effect of sowing dates and initial period of cutting on forage yield of oat (*Avena sativa* L.). The experiment was laid out in split plot where the main plot consisted of three different dates of sowing (15th October, 30th October and 14th November) and two varieties (Palampur-1 and JHO 99- 2), whereas subplot had three initial periods of cutting (60, 75 and 90 DAS). All growth parameters were affected significantly by the initial period of cutting. The oat initially cut at the 90 days after sowing recorded significantly a greater number of tillers·metre^{-1} row length, number of leaves·plant^{-1} and leaf : stem ratio than the oat initially cut at 60 and 75 days after sowing. This may be due to a greater number of tillers in the treatment of initial period of cutting at 90 days after sowing which produced a greater number of leaves. But in case of plant height oat initially cut at the 60th day growth stage produced taller plants than the oat initially cut at 75 and 90 days after sowing. The oat initially cut at 90th days after sowing recorded significantly higher green weight and dry weight than the oat initially cut at 60 and 75 days after sowing. The increase in green weight with initial cut at 90 days after sowing may be due to differences in plant height and number of tillers metre^{-1} row length which were significantly higher in this treatment. The other possible reason may be due to more time provided to the crop for forage. The oat initially cut at 90 days after sowing recorded significantly higher green fodder and dry fodder yield than the oat initially cut at 60 and 75 days after sowing. It was revealed that initial cutting at 90 days after sowing resulted in 31.9 and 14.9 q ha^{-1} higher green fodder yield and 6.8 and 3.2 q ha^{-1} higher dry fodder yield over initial cut at 60 and 75 days after sowing, respectively. The oat initially cut at 90 days after sowing and left for seed production recorded significantly highest forage yield (114.06 q ha^{-1}) than the oat initially cut at 60 and 75 days after sowing (DAS). Initial period of cutting at 90 days after sowing had significantly taller plants, higher tillers metre^{-1} row length, higher green and dry weights and significantly more leaves compared to initial period of cutting at 60 and 75 days after sowing which reflected in increased green forage yield through their cumulative effect, as the yield unit area^{-1} in forage crops is the resultant of number of plants unit area^{-1} and weight plant^{-1}. The later depends upon growth characters viz. plant height, tillering capacity and growth rate. Moreover, the crop was in early growth stages when it was initially cut at 60 and 75 days after sowing. Crude fibre content was significantly increased with each delay in initial period of cutting. This was best obvious on the crop under delayed cutting at 90 days after sowing got enough time in the field to fiberized the various plant organelles. The higher dry matter production is testimony to this effect. Delayed cutting at 90 days after sowing increased the dry matter yield and resulted in corresponding decrease in crude protein content because of dilution effect. The trend of decrease in protein content with increase in yield is in conformation with the inverse yield nitrogen low.

AL-dulami and AL-khalifawi (2016) conducted a field experiment to investigate the effect of sowing date (10th Oct, 20th Oct, 30th Oct and 9th Nov) and cutting date (45, 60, 75 day from sowing) in some of growth characteristics, fodder yield and quality of oat (cv. Shofan 11). The results were summarized as follows: Cutting date after 75 day from sowing was superior in case of most of the traits in first cut; plant height (87.66 cm), number of leaves (6.97 leaf plant^{-1}), stem diameter (5.40 mm), fresh and dry weight of fodder (46.58 and 6.27 ton. ha^{-1}) respectively. As for second and third cutting dates, the first date was superior in most traits under study (e.g. plant height, number of leaves, stem diameter and fresh fodder); their averages for fresh weight of fodder were 21.90, 19.90 ton. ha^{-1} and dry weight of fodder 2.69, 2.72 ton. ha^{-1} for the second and third cut, respectively.

Alipatra *et al.* (2013) conducted an experiment to observe the yield and quality improvement in fodder oats (*Avena sativa* L.) through split application of fertilizer and cutting management. The experiment consisted of cutting management at two levels (C_1 = single cutting at 80 DAS and C_2 = double cutting at 60 DAS and at 105 DAS). Seeds of oat variety JHO-822 were sown. Under double cut management the yields of forage oats were higher than that of single cut management practice.

Jehangir *et al.* (2013) conducted a two-year study to find out the influence of sowing dates, fertility levels and cutting management on growth, yield and quality of oats. The treatments consisting of three sowing dates (September 20, September 30 and October 10), three fertility levels (150:70:40, 125:60:30, 100:50:20 kg $N:P_2O_5:K_2O$ ha^{-1}) and two cuttings managements (Single cut - cut at 50% flowering and double cut - cut on 15th December and 50% flowering). Oat variety "Sabzar" was sown as per treatment. The results showed that oat plants with single cut treatment had taller plants, higher number of tillers m^{-2} and higher leaf area index compare to double cut receiving plants. The results also revealed that double cut crop recorded 14.75% and 16.24% increase in green fodder yield and 3.70% and 1.36% in dry fodder yield over single cut crop during

2009–10 and 2010–11, respectively. Moreover, double cut crop recorded higher crude protein content but lower crude fibre content.

Patel *et al.* (2013) conducting field experiments to assess the requirement of cutting management and schedule of N application in oat (*Avena sativa* L.) and their effect on growth, yield and economics for three years. The present study indicated that cutting management significantly affected the seed and straw yield and green fodder yield. No cut treatment (C_0) increased seed yield by 11.29% and 29.80% and straw yield by 13.68% and 44.11% over cutting at 30 and 45 days after sowing (DAS). Contrary to this, significantly the highest green fodder yield (143.83 q ha^{-1}) was obtained with cutting at 45 DAS than crop was left for seed production. Net return (Rs. 64167) and B:C ratio (2.89) obtained were higher with no cutting treatment.

Kumar (2012) carried out the field investigation entitled "Effect of date of sowing and cutting management on oats (*Avena sativa* L.) fodder" under irrigated conditions. The experiment was consisted of four dates of sowing i.e.1 October, 11th October, 21st October and 31st October in main plots and five cutting managements i.e. single cut at 50% flowering, two cuttings (first cut at 55 days, second cut at 50% flowering), two cuttings (first cut at 65 days, second cut at 50% flowering), three cuttings (first cut at 55 days, second cut at 45 days after first cut and third cut at 50% flowering) and three cuttings (first cut at 65 days, second cut at 45 days after first cut and third cut at 50% flowering) in sub plots. The green fodder yield was significantly higher in three cut management (first cut at 55 days, second cut at 45 days after first cut & third cut at 50% flowering) i.e. 639.20 q ha^{-1} followed by two cut management system, first cut at 55 DAS and second cut at 50% flowering i.e. 624.77 q ha^{-1}, however, the dry fodder yield was recorded the highest in two cut management system, first cut at 55 DAS and second cut at 50% flowering i.e. 108.21 q ha^{-1} with lesser lodging and better quality parameters viz. crude protein content (12.64, 10.41) and production (11.91 q ha^{-1}), ether extract content (2.61, 1.85) and production (2.45 q ha^{-1}) and total ash content (9.40, 8.36) and production (8.34 q ha^{-1}). NDF and total carbohydrate production were also the highest in two cut management system when compared to single and three cut management system. Significantly higher net returns (Rs 51391 per ha) and benefit∶cost ratio (1.06) was obtained in two cut management system which not only produced higher dry matter but also improve the availability over longer span of time.

Bhilare and Joshi (2007) conducted a field experiment was during two consecutive winter (*rabi*) seasons of 2003–04 and 2004–05 to study the effect of cutting management and nitrogen levels on quality of oat (*Avena sativa* L.). Pooled results revealed that single cut at 50% flowering recorded significantly higher dry-matter (8.05 $t \cdot ha^{-1}$) and digestible dry-matter yields (5.0 $t \cdot ha^{-1}$), dry-matter content (20.85%), acid-detergent fibre (48.14%), neutral detergent fibre (59.56%) and hemicellulose content (23.02%) than double-cutting system. But total crude-protein yield (805 kg ha^{-1}), crude-protein content at both the cuts (18.70% and 10.55% respectively), digestibility (76.31%), ash (10.44%) and cell contents (56.79%) at the first cut were significantly higher when the first cut was taken at 50 days after sowing and the second cut at 50% flowering. However, at second cut, digestibility (66.72%), ash (10.34%) and cell contents (43.47%) were statistically more when the first cut was taken at 60 days after sowing and the second cut at 50% flowering.

Sharma *et al.* (2001) conducted a field experiment to study the effect of cutting management, method of sowing and nitrogen doses on forage and grain yield of oat (*Avena sativa* L.). No-cut treatment gave higher grain (26.05 and 28.40 q ha^{-1}) and straw (82.83 and 86.55 q ha^{-1}) yields than cutting at 65 or 85 days after sowing. However, higher fodder yield (158.08 and 168.80 q ha^{-1}) was recorded when cutting was performed at 85 days. Net returns (Rs 15,619) and benefit ∶ cost ratio (2.50) were higher with 1 cutting at 65 days and then the crop was left for grain production. Fodder cut at 65 DAS and at 50% flowering stage gave 30.65% and 21.62% higher net returns over oats cut at 85 DAS and 50% flowering and only one cut at 50% flowering, respectively.

Hasan and Shah (2000) carried out a field trial to study the effect of 4 cutting regimes and 5 graded doses of nitrogen on oat biomass production (fodder, grain and straw) and quality. Plant height and number of tillers were adversely affected by increasing cutting intensity. The grain yield attributes (panicle m^{-1} row length, grains $panicle^{-1}$ and test weight) were all favourably placed in a no-cut system and increased nitrogen levels up to 80 kg ha^{-1} helped to improve these as well. Maximum green and dry fodder were recorded with two cuts (one each in autumn and spring) whereas maximum grain or straw was obtained when crop left for seed only. The highest protein yields ha^{-1} were obtained in a pure grain crop of oats or in that crop where two cuts were taken.

Mutti (1995) reported that oat crop sown on November 6 in combination with one cut for fodder and then grain from the regenerated crop gave the highest average net returns to the tune of Rs 9297 per hectare.

Midha *et al.* (1994) concluded that different cutting management in oat was found to influence quality of fodder yield. Each delay in fodder cutting from 50 DAS to 80 DAS found to decrease protein content of fodder significantly and increase in ADF (Acid Detergent Fibre) and NDF (Neutral Detergent Fibre) content while there was no effect on Ether Extract content. They further explained that protein content with delay in cutting decreased because of higher fodder yield which led to dilution of photosynthates. Unlike protein content, ADF and NDF content increased because of increase in fibre content of plant with increasing age. However, the total production of crude protein, Ether extract, ADF and NDF increased with each delay in cutting because of increase in fodder yields of oat.

2.5 Comparative effect of cutting management on different crop species

Salama *et al.* (2021) carried out two experiments where the first one investigated the forage productivity and in vitro quality of a single cut taken at different plant ages (45, 60, and 75 days after sowing—DAS) from four prominent cereal crops, namely, barley, oat, triticale, and ryegrass, grown during two successive winter seasons in Northern Egypt. Statistical analysis revealed that the age of plant at forage removal significantly affected the barley number of fertile spikes and harvest index, oat plant height, number of fertile spikes, number of grains spike^{-1}, 1000-grain weight, and grain yield, all triticale parameters except the number of grains spike^{-1}, and all ryegrass parameters except 1000-grain weight. It was clear that early forage removal at 45 DAS resulted in the production of the tallest significant plants of oat, ryegrass, and triticale, while later harvests at 60 and 75 DAS resulted in shorter plants. Forage removal at 45 and 60 DAS for barley, oat, and triticale, as well as at 60 DAS for ryegrass, resulted in the highest significant number of fertile spikes. Differences between the highest and lowest number of fertile spikes reached 26.30%, 24.28%, 24.91% and 34.10% for barley, oat, triticale, and ryegrass, respectively. Nonetheless, the highest significant number of grains spike^{-1} was reached when forage was removed at 45 and 60 DAS for oat and at 45 DAS for ryegrass. Similarly, early and intermediate forage removal at 45 and 60 DAS resulted in the heaviest significant 1000-grain weight for oat and triticale. The highest total yield was achieved with early forage removal at 45 DAS for ryegrass and at 45 and 60 DAS for triticale. Grain yield followed the same trend with forage removal at 45 and 60 DAS resulting in the highest significant grain yield from oat, triticale, and ryegrass. A reduction in grain yield for the three respective crops from forage removal at 45 DAS to forage removal at 75 DAS amounted to 25.81%, 44.64% and 30.06%. Harvest index values were the highest significant when barley forage was removed at 45 DAS (19.94%), triticale forage was removed at 60 DAS (15.62%), and ryegrass forage was removed at 45 DAS (10.72%), and 60 DAS (11.98%). Despite the progressive increase in the fresh and dry matter yields produced from the four crops with later forage removal and the relatively high quality of the forage removed at 45 DAS, 1st experiment concluded that forage removal at 60 DAS produced a reasonable amount of fresh and dry matter yields with appropriate in vitro quality. Meanwhile, the gain in forage yield, when forage was removed at 60 DAS, was enough to compensate for the consequent reduction in grain yield of the four evaluated crops. In growing dual-purpose cereals, it was recommended to cut the crops at 60 DAS to achieve the optimum balance between forage yield and quality on the one hand and final grain yield on the other hand.

Netthisinghe *et al.* (2020) compared wheat forage production, grain yield, and growth performance of beef cow–calf pairs grazed on wheat pasture for 2–3 weeks in spring with the conventional wheat (*Triticum aestivum* L.) grain production system and stockpiled tall fescue (*Festuca arundinacea* (L.) Schreb) pasturing in a two-year study. Grazing wheat resulted in grain yield (4.1 vs. 4.6 $t \cdot ha^{-1}$) and test weight (65.9 vs. 66.7 kg hL^{-1}) similar to the conventional grain production system. Wheat accumulated significantly lower forage dry matter yield (0.9 vs. 1.9 $t \cdot ha^{-1}$) in spring with higher crude protein (190.2–290.2 vs. 122.0–151.0 g kg^{-1}) and low fiber contents compared to the stockpiled tall fescue pasture. Wheat pasture presented risk for the development of grass tetany with regard to N, K, Na, and Mg contents. Calves grazed on wheat gained 1143–1370 gd^{-1} body weight compared to the 826–879 gd^{-1} in the stockpiled tall fescue pasturing. Cows had inconsistent and mixed body weight change response. With warmer temperatures and adequate precipitation, controlled grazing of wheat in spring by beef cow–calves offered weight gain benefits exceeding the stockpiled tall fescue pasturing and grain production similar to the conventional wheat grain system.

Satpal *et al.* (2019) conducted a field experiment to study the performance of dual-purpose oat, wheat and barley under different cutting management system. Three crops *i.e.* oat, wheat and barley and four cutting management *i. e.* no cutting, cutting for fodder at 50, 60 and 70 days after sowing (DAS) were replicated thrice under split plot design. Second cut was taken for grain in all the treatments except for no cut. The varieties used were HJ 8, WH 1164 and RD 2035 for oat, wheat and barley, respectively. Among crops, oat produced the maximum green fodder, dry matter followed by barley. However, wheat produced the maximum grain yield followed by barley. Among different cutting management practices, maximum green fodder and dry matter yield were recorded when cut was taken 70 DAS and then left for grain. Wheat crop produced the highest grain and the second highest straw yield and thereby fetched highest B:C ratio (2.16). Based on the results, it could be concluded that among the crops i.e. oat, barley and wheat, all the three crops suited for dual purpose but crop selection should be based on the priority of end user. If the priority was to get more green fodder from first cut then oat could be first choice followed by barley and wheat. Besides this, the cutting management schedule needs to be standardized. The green fodder yield increased significantly as the number of days to cut increased from 50 to 70 from sowing. But the grain yield decreased significantly as the cutting schedule was advanced from 50 days onward. Based on the economic analysis, wheat was the most remunerative crop followed by oat for dual purpose. If compared with no cut where remunerations were highest, the cut at 50 DAS was most beneficial.

Makarana *et al.* (2018) undertook a study to assess the production potential and quality of different pearl millet accessions under saline environment. The experiment was conducted with treatments consisting 20 pearl millet accession and 2 cutting management. Two cuttings at 50 and 110 DAS resulted in maximum DM content (19.47%), Total Dry matter yield (12.16 $t \cdot ha^{-1}$), crude protein content (8.03%), and acid detergent fibre (ADF) content (37.56%), however the maximum Ether extract (3.06%) and neutral detergent fibre (NDF) content (68.69%) observed under three cuttings each at 50, 80 and 110 DAS treatment. Therefore, accession ICFH-15 and among cutting management strategies, single cut for green fodder followed by harvest for grain might be adapted for getting higher dry matter yield with better quality under saline environment.

Beji (2016) conducted a study aimed at evaluating agronomic performances and grain quality of two dual-purposes cereal crops, Barley and Triticale, cut at the pseudo stem erect stage (C30). The trial was conducted during 2010–2011 and 2011–2012 seasons under a semi-arid environment. The semi-arid region of Tunisia is characterized by a low and erratic rainfall. This makes year-round maintenance of pasture and forage production under non-irrigated conditions both costly and difficult. In order to fill the winter feed gap in the livestock cycle; some cereals can be used as dual-purpose. The results from the study revealed that yields did not significantly differ between years and although barley yielded more forage crop than triticale but the yield was not significantly different. Crude protein in the plant was significantly higher in barley (18.2%) compared to triticale (17.4%). Defoliation has caused a significant grain yield reduction for both cereals and was about 22% for triticale and 28% for barley; grain yield after forage removal was statistically higher for triticale (3.47 $t \cdot ha^{-1}$) than barley (2.85 $t \cdot ha^{-1}$). As average for the two seasons of the trial, grain protein was significantly higher after clipping for barley (11.35% for dual purpose and 10.17% for grain production only) and was not affected for triticale (9.38% versus 9.55%). Under Tunisian semi-arid environment, triticale and barley have comparable yields with a small superiority for triticale in grain yield after forage use and higher plant and grain protein contents in barley.

Jha *et al.* (2016) conducted an experiment to find out the effect of cereal crops (Wheat, Oat, Barley) and cutting schedule on forage and grain yield. The experimental material consisted of 3 cereal crops *viz.*; Wheat (VL829), Oat (RD2552), Barley (JO1) as main plot treatments and 4 cutting dates i.e. no cutting wheat (C_1), single cutting at 50 days after sowing (DAS) (C_2), single cutting 60 at DAS (C_3) and single cutting at 70 at DAS (C_4) respectively as sub-plot treatment. The study revealed the maximum chlorophyll accumulation in Barley and wheat during the initial stage at 95 DAS and wheat and barley during reproductive stage at 30 DAS. Cutting at 50 DAS is proved beneficial on chlorophyll accumulation. Photosynthetic rate was the maximum in wheat at 90 DAS. However, cutting did not affect photosynthesis rate, stomatal conductance and transpiration rate. Barley gave maximum fodder yield (fresh/day). Cutting at 50 DAS was beneficial in producing maximum fodder yield without sacrificing grain yield of cereal crops. Wheat was recorded with the maximum protein (13.46%) and carbohydrate (69.66%) contents, whereas Oat recorded the maximum fibre content (12.57%), respectively. In sub-treatments, C_1 had the maximum protein (13.38%) and C_3 had the maximum fibre contents (11.99%), whereas C_2 (71.28%) was recorded with the maximum carbohydrate content.

Sharma (2015) evaluated Sixteen genotypes of barley and eight genotypes of oat for green fodder and seed yield. Fodder cut was taken at 53 days after sowing and regenerated crop managed for grain production. Green fodder yield of oat genotypes ranged between 56.00 and 130.33 q ha^{-1} with the average of 94.28 q ha^{-1}; however, in barley it varied between 119.50 and 238.50 q ha^{-1} with the average of 178.70 q ha^{-1} at 53 days after sowing. The seed yield of regenerated oat varied between 6.98 and 20.57 q ha^{-1} with the average yield of 14.50 q ha^{-1}; and in barley it ranged between 19.79 and 47.43 q ha^{-1} with the average of 31.29 q ha^{-1}. This high degree of variability among genotypes of oat and barley revealed a good scope of selection. Genotypes OS-387, JO-09-504, JHO-2012-5, JHO-822 and UPO-212 of oat and RD-2035, BH-971, Azad, UPB-1035, UPB-1036, UPB-1034, RD-2715 and RD-2552 of barley appeared relatively better for green fodder and seed yield in dual purpose cultivation. The plant height and green fodder yield of barley at 53 days after sowing were 42.80% and 89.54% higher over oat, which indicated that growth and biomass production ability of barley at early stage was higher than oat. In regenerated crop, seed yield and test weight of barley were 115.79% and 46.32% higher over oat. However, plant height and biological yield of regenerated oat were 23.96% and 20.73% higher than barley. It indicated that regeneration capacity of oat was better than barley but seed production potential of barley was much higher than oat. Economic analysis revealed that total income received from green fodder, seed and straw yield of barley was Rs. 104262.00 ha^{-1}, however, in case of oat, it was Rs. 81710.00. Therefore, the cultivation of dual-purpose barley appeared to be more beneficial than oat and an additional income of Rs. 22552 ha^{-1} might merely be earned if barley was cultivated in place of oat.

Harrison *et al.* (2012) opined that growing cereal crops for the dual-purposes (DP) of livestock forage during the early vegetative stages and harvesting grain at maturity has been practised for decades. It followed that scientific experiments using DP crops are nearly as old. A survey of more than 270 DP crop experiments revealed that the average effect of crop defoliation on grain yield (GY) was—7 ± 25% (range—35 to 75%). In light of these results, the first purpose of this review was to assess how alternative crop and grazing management regimes affected forage production and GY. Management techniques in order of decreasing importance likely to maximise grain production include (i) terminating grazing at or before GS 30, (ii) matching crop phenology to environment type, (iii) sowing DP crops 2–4 weeks earlier than corresponding sowing dates of grain-only crops, and (iv) ensuring good crop establishment before commencement of grazing. The second aim was to identify the environmental and biotic mechanisms underpinning crop responses to grazing, and to identify crop traits that would be most conducive to minimising yield penalty. A variety of mechanisms increased GY after grazing. Under favourable conditions, increased GY of grazed crops occurred via reduced lodging, mitigation of foliar disease and rapid leaf area recovery after grazing. Under stressful conditions, increased yields of grazed crops were caused by reduced transpiration and conservation of soil water, delayed phenology (frost avoidance at anthesis), and high ability to retranslocate stem reserves to grain. Yield reductions caused by grazing were associated with (i) frost damage soon after grazing, (ii) poor leaf area development or (iii) delayed maturation, which led to water or temperature stress around anthesis, culminating in increased rates of green area senescence and decreased duration of grain-filling. The third aim was to examine the role of simulation models in dissecting the effects of environment from management on crop physiology. Simulation studies of DP crops have extended the results from experimental studies, confirming that forage production increases with earlier sowing, but have also revealed that chances of liveweight gain increase with earlier sowing. Recent modelling demonstrated that potential for inclusion of DP crops into traditional grain-only systems is high, except where growing-season rainfall is < 300 mm. Prospective research involving crop defoliation should focus on crop recovery, specifically (i) the effects of defoliation on phenology, (ii) the time-course of leaf area recovery and dry matter partitioning, and/or (iii) development of crop-grazing models, for these three areas will be most conducive to increasing the understanding of crop responses to grazing, thereby leading to better management guidelines.

Broumand *et al.* (2010) conducted an experiment in order to evaluate the effects of forage clipping and utilization of nitrogen as a top dress fertilizer, on grain yields of some cereals in dual purpose cultivation. The combination of two nitrogen fertilizer as a top dress fertilizer (0 and 250 kg ha^{-1} in two stages) forms urea source and forage clipping were considered as main factor, and different cereals (wheat, barley, rye and triticale) were sub-factor. Forage clipping had significant effect on the number of $spikes \cdot m^{-2}$, the number of grains in spike, grain yield, 1000-grain weight, stem height, percentage of lodging, straw yield, chlorophyll content and solar radiation absorption. All parameters were significantly influenced by cultivation of cereals. The highest straw yield, grain yield and 1000-grain yield were obtained from triticale. It was concluded that dual purpose cultivation system had negative influence on grain yield. However, application of nitrogen as a top-dress fertilizer could minimize these adverse effects. Cultivation of barley and triticale showed considerable advantages than other crops.

Francia *et al.* (2006) reported higher biomass production of barley than oat in dual-purpose systems in Mediterranean Italy.

Sharma (2002) compared the relative performance of oat and barley cultivars for forage yield and reported green and dry fodder yield superiority of barley over oat.

Royo and Tribó (1997) conducted four field experiments where two 6-rowed barley varieties, 3 spring triticales, and 2 winter triticales were evaluated for grain yield and for forage and grain production in the same cropping season. Forage was cut at the first node detectable stage and grain was harvested at ripening in both cut and uncut plots. Forage and grain yields did not differ significantly between species. Forage yield was positively and strongly related to the time between sowing and cutting. Forage quality and grain protein content were similar in barley, spring triticale, and winter triticale. Forage crude protein averaged 25.3%, digestible crude protein 19.4%, and acid detergent fibre 21.9%. Grain protein content averaged 15.4%. The reduction in grain yield caused by clipping ranged from 7 to 70% in barley, 10 to 21% in spring triticale and 8 to 24% in winter triticale. Grain yield after cutting decreased drastically when the thermal time between cutting and physiological maturity was lower than 1000 growing degree-days (GDD), being independent of this duration for values >1100 GDD. Reductions in grain yield after forage removal were caused mainly by reductions in grain weight. A strong relationship appeared between grain yield in the uncut treatment and grain yield after forage removal, suggesting that breeding for dual purpose could take advantage of the efforts made to increase grain yield potential.

Hussain *et al.* (1995) reported that oats harvested at booting stage and barley at 100% flowering stage gave the maximum green-fodder yields (79.45 and 63.10 $t\cdot ha^{-1}$ respectively). In both oat and barley crops, the highest DM (dry matter) yields (15.54 and 13.75 $t\cdot ha^{-1}$ respectively) were recorded at the early dough stage. In both the crops, crude protein contents decreased with the advancement in crop maturity. The maximum crude protein content (14.93% and 14.37% in oats and barley respectively) was observed when the crops were cut repeatedly at the 4-leaf stage, whereas the minimum was at early dough stage in both the crops. Oats and barley harvested at the booting stage gave reasonable green-fodder yield (mean 67.32 $t\cdot ha^{-1}$), DM yield (11.66 $t\cdot ha^{-1}$) and fodder quality (crude protein 10.33%).

Andrews *et al.* (1991) compared two newly registered cultivars of triticale, Tiga and Empat, with existing commercial cultivars of triticale, cereal rye and forage oats, for grain yield and dry matter production. Their performance was evaluated at Armidale, New South Wales, over 3 years with varying defoliation regimes (uncut to grain yield, cut in late autumn, cut in autumn and winter, and cut in winter only). Phenological observations confirmed that Tiga and Empat were midseason cultivars, intermediate between Coolabah and Blackbutt oats. Autumn and winter forage production and organic matter digestibility of Tiga and Empat were equal to those obtained from Cooba and Blackbutt oats. Grain yields (up to 4.0 $t \cdot ha^{-1}$) of the highest yielding triticale cultivar (Empat) were equal to, or greater than, the best oats cultivar (Blackbutt). Generally, the highest winter growth rates, dry matter yield at maturity and grain yield were recorded from uncut plots, except in the early oats cultivar Coolabah which, in 1 experiment, lodged in spring if left undefoliated through autumn and winter. Cutting only in autumn had small effects (negative) on grain yields, but cutting in both autumn and winter reduced total dry matter yields at maturity by 30% and grain yields by 50%. Cutting only in winter resulted in higher vegetative forage yields than a double cut (autumn and winter), but the single winter cut subsequently produced lowest dry matter yields at maturity. The high grain yields of triticale were linked to rapid spring growth. Harvest indices of triticale cultivars were generally lower than those of the oat cultivars. The results indicated the potential of triticale, especially cv. Empat, as a dual-purpose forage and grain crop.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods of the experiment with a brief description on experimental site, climate, soil, land preparation, planting materials, experimental design, 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 Experimental period

The experiment was conducted at the research field of the department of Agronomy, Sher-e-Bangla Agricultural University during the period from November, 2019 to March, 2020.

3.2 Geographical location

The experimental site was located at 23°46′ N latitude and 90°23′ E longitude with an altitude of 8.45 m.

3.3 Agro-Ecological Region

The experimental site belongs to the agro-ecological zone of “Madhupur Tract”, AEZ-28 [Appendix II(A)]. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (FAO-UNDP, 1988). For better understanding, the experimental site is shown in the AEZ Map of Bangladesh in Appendix I(A).

3.4 Climate and weather

The geographical location of the experimental site was under the sub-tropical climate characterized by three distinct seasons. The monsoon or rainy season extending from May to October, which is associated with high temperature, high humidity and heavy rainfall. The winter or dry season from November to February, which is associated with moderately low temperature and the pre-monsoon period or hot season from March to April, which is associated with less rainfall and occasional gusty winds. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity and sunshine during the period of study of the experimental site was collected from Bangladesh Meteorological Department, Agargaon and is presented in Appendix IV.

3.5 Soil

The soil of the experimental area was silty clay in texture, red brown terrace soil type, olive–grey with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 5.5 and had organic carbon 0.43% [Appendix II(B)]. The land was well drained with good irrigation facilities. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. The morphological characters of soil of the experimental plots are as following - Soil series: Tejgaon, General soil: Non-calcareous dark grey [Appendix I(B)]. The physicochemical properties of the soil are presented in Appendix II.

3.6 Planting materials

Improved variety of wheat (BARI Gom-33), triticale (BARI Triticale-1), barley (BARI Barley-1) and local variety of oat was used as planting material for the present study. These varieties are recommended for rabi season. The seeds were collected from BARI and local market.

3.7 Treatments

The experiment consisted of two sets of treatments. The treatments were different cereal crops and cutting managements. Cutting management treatments were applied at 5 cm above ground. The treatments are mentioned below:

Factor A: Cutting management (3)

i. Uncut - C_1
ii. One cut at 25 DAS - C_2
iii. Two cuts at 25 DAS and 61 DAS - C_3

Factor B: Cereal crops genotype (4)

i. Wheat (BARI Gom-33) - G_1
ii. Triticale (BARI Triticale-1) - G_2
iii. Barley (BARI Barley-1) - G_3
iv. Oat - G_4

3.8 Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three (3) replications. Total 36 unit-plots were prepared for the experiment. Each plot was of (3.00 × 1.50) m^2 = 4.50 m^2 in size (Appendix III).

3.9 Seed cleaning

Seeds were cleaned up by separating the seeds from any other types of seed, odd looking seed, inert matter (bricks, stones) etc.

3.10 Sterilization of seed

Prior to sowing, the seeds were surface sterilized with Autostin 50WDG. 2 to 3 gm of Autostin 50WDG for per kg seed was mixed with small amount of water and then the seeds were sterilized for 20 minutes on 26 November 2019.

3.11 Final land preparation

The land was first opened with a tractor drawn disc plough on 24 November 2019. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were cleared off from the experimental field. The final land preparation was done and subsequently field layout was completed on 25 November 2019 according to experimental specification.

3.12 Fertilizer application

The land was fertilized at 25 November 2019 with cow dung, urea, triple super phosphate, muriate of potash, gypsum, boric acid and zinc sulphate according to the following table:

Nutrient	Source	Dose
Organic fertilizer	Compost/Cow dung	10.00 $t \cdot ha^{-1}$
N (Nitrogen)	Urea (46% N)	160.00 kg ha^{-1}
P (phosphorus)	TSP (20% P_2O_5)	150 kg ha^{-1}
K (potassium)	MoP (60% K_2O)	110 kg ha^{-1}
S (Sulphur)	Gypsum (18% S)	125 kg ha^{-1}
B (Boron)	Boric acid (16.50% B)	6.50 kg ha^{-1}
Zn (Zinc)	Zinc sulphate (36% Zn)	12.50 kg ha^{-1}

The whole amount of triple super phosphate, muriate of potash, gypsum, boric acid and zinc sulphate were applied at the time of final land preparation. Urea was applied in two equal splits at 20 and 40 DAT at 15 December 2019 and 5 January 2020, respectively.

3.13 Sowing of seeds

Seeds were sown on 28 November, 2019 by hand. 1.75 kg seed (55 g seed $plot^{-1}$ of wheat, barley and oat and 28 g seed $plot^{-1}$ of triticale) were sown in line at recommended rate and then covered properly with soil. The line to line distance for the cereal crops was 25 cm and plant to plant distance was 5 cm, thus plant spacing was 125 cm^2. There were 10 row per plot.

3.14 Intercultural operation

The following intercultural operations were done for ensuring the normal growth of crop:

3.14.1 Thinning

Emergence of seedling was seen within 10 days after sowing. Overcrowded seedlings were thinned out. Thinning was performed after 20 days of sowing on 15 December, 2019 which was done to remove unhealthy and lineless seedlings.

3.14.2 Weeding

The experimental field was kept free from weeds by hand weeding as per requirements.

3.14.3 Irrigation

The first irrigation was done at crown root initiation stage (20 DAS) on 15 December, 2019. Second irrigation was provided at 40 DAS on 5 January 2020. Well managed drainage system was also installed for draining out excess water.

3.14.4 Plant protection measures

Field was infested by Fusarium or Sclerotium root rot during the early growing stage of seedlings. Spraying Bavistin at recommended dose controlled these fungi. The fungicide was sprayed three times at 7–10 days interval. Rodents were also controlled by using rodenticide at recommended dose. The crop was protected from birds and rats during the grain-filling period. Zinc phosphide was applied to control rat. Net was given to protect the cereal grain from bird especially parrots.

3.15 General observations of the experimental field

Regular observation was done to inspect the growth stages of the crop. The field was observed time to time to detect any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized.

3.16 Application of cutting treatments

Different levels of cutting management treatments (One cut at 25 DAS and two cuts at 25 DAS and 61 DAS) were applied on wheat, triticale, barley and oat plants at 5 cm above ground by scissor/sickle.

3.17 Sampling

Five plants of the inner rows from each plot were selected randomly and growth and yield parameters data were taken from these 5 plants at maturity.

3.18 Harvesting and post-harvest operation

The wheat, triticale, barley and oat plants were harvested depending upon the maturity. Harvesting was done manually from each plot. Maturity of crop was determined when 80% of the grains became white shiny in colour. At maturity, when leaves, stems and spikes became yellowish in colours, then the plants were harvested. One square meter area from the central position of each plot was harvested for yield data and it was converted to $t \cdot ha^{-1}$. The selected sample plants were then harvested, bundled, tagged and carefully carried to the threshing yard in order to collect data. The crop bundles were sun dried by spreading those on the threshing floor. The grains were separated from the plants by beating the bundles with bamboo sticks and thereafter were cleaned, dried and weighed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and sun dried for 3 days. Straw was also sun dried properly. The weights of the sun-dried straw were also taken from the same demarcated area and were converted to $t \cdot ha^{-1}$.

3.19 Recording of data

The growth parameters during study were recorded at 20 days interval started from 40 DAS up to 80 DAS from plants grown in the plot while the yield data and other parameters were collected at harvest.

3.19.1 Crop growth parameters

a) Plant height
b) Number of tillers m^{-2}
c) Number of leaves $plant^{-1}$
d) Leaf area index (LAI)
e) Fresh weight (g)
f) Dry weight (g)

3.19.2 Yield contributing parameters

a) Number of grains $spike^{-1}$
b) Number of unfilled grains $spike^{-1}$
c) Weight of grains $spike^{-1}$
d) Spike length

3.19.3 Yield parameters and harvest index

a) Grain yield
b) Straw yield
c) Biological yield
d) Harvest index

3.19.4 Fodder weight

a) Fodder fresh weight
b) Fodder dry weight

3.20 Procedure of data collection

3.20.1 Crop growth parameters

3.20.1.1 Plant height

The plant height of cereal plant was considered from the top surface level of soil to the tip of the longest leaf at booting stage and flowering stage. At maturity stage, the plant height of cereal plant was measured from the top surface level of soil to the tipper end of the longest spike. Plant height was measured at three growth stages (40 DAS, 60 DAS and 80 DAS) from five plants in each plot and the average was recorded in centimetre.

3.20.1.2 Number of tillers m^{-2}

Number of tillers m^{-2} was counted at 40, 60 and 80 DAS by counting total tillers within one square meter area from the central position of each plot.

3.20.1.3 Number of leaves $plant^{-1}$

Number of leaves $plant^{-1}$ was counted at 40, 60 and 80 DAS by counting total number of leaves individually from five plants in each plot and the average was recorded as number of leaves $plant^{-1}$.

3.20.1.4 Leaf area index (LAI)

Leaf area index was calculated by using the following formula:

$$\text{Leaf area index} = \frac{\text{Leaf length (cm)} \times \text{Leaf breadth (cm)} \times \text{number of leaves plant}^{-1}}{\text{Plant spacing (cm}^{2}\text{)}}$$

Leaf length was measured from the leaf base attached to the stem to leaf tip. Leaf breadth was calculated by taking measurement of breadth from three parts of each leaf and taking the average value as the leaf breadth from five plants in each plot.

3.20.1.5 Fresh weight

Fresh weight of plant was recorded at the time of 40, 60 and 80 DAS by collecting fresh whole plant samples. Data were recorded as the average of 5 sample plants plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.20.1.6 Dry weight

Dry matter weight of plant was recorded at the time of 40, 60 and 80 DAS by drying whole plant samples. The total plant was oven dried at 72°C temperature until a constant level from which the weight of plant dry matter was recorded. Data were recorded as the average of 5 sample plants plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.20.2 Yield contributing parameters

3.20.2.1 Number of grains spike^{-1}

The total number of grains spike^{-1} was collected randomly from grains of 5 spikes plant^{-1} from 5 individual plants and then average number of grains spike^{-1} of cereal plant was recorded.

3.20.2.2 Number of unfilled grains spike^{-1}

The total number of unfilled grains spike^{-1} was collected randomly from unfilled grains of 5 spikes plant^{-1} from 5 individual plants and then average number of unfilled grains spike^{-1} of cereal plant was recorded.

3.20.2.3 Weight of grains spike^{-1}

Cleaned and dried grains from 5 spikes plant^{-1} from 5 individual plants were collected randomly from each plot and weighed by using a digital electric balance. When the grains retained 12% moisture, then the average weight of grains spike^{-1} of cereal plant was recorded and expressed in gram.

3.20.2.4 Spike length

The length of spike was measured with a meter scale from 5 selected spikes plant^{-1} from 5 individual plants and the average value was recorded and expressed as spike length of that cereal in cm.

3.20.3 Yield parameters

3.20.3.1 Grain yield

After proper drying, the grain yield of 1 m^2 area was recorded which had effective tillers from each plot in 1 m^2 area and expressed on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester. Grain yield was then converted into t ha^{-1}.

3.20.3.2 Straw yield

Straw yield was determined from each plot, after separating the grains. The sub-samples were oven dried to a constant weight. Straw yield was finally converted into t ha^{-1}.

3.20.3.3 Biological yield

Biological yield was determined using the following formula:

Biological yield (t ha^{-1}) = [Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})]

3.20.3.4 Harvest index

Harvest Index denotes the ratio of economic yield to biological yield. Harvest index was determined with the following formula of Donald (1963):

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total dry weight)}} \times 100$$

It was expressed in percentage.

3.20.4 Fodder weight

3.20.4.1 Fodder fresh weight

Fresh weight of fodder was collected from C_2 and C_3 treatment within one square meter area from the central position of each plot and expressed in gram.

3.20.4.2 Fodder dry weight

The fodder which was collected from C_2 and C_3 treatment within one square meter area from the central position of each plot, was oven dried at 72°C temperature until a constant level from which the weight of fodder dry matter was recorded and expressed in gram.

3.21 Statistical analysis

The collected data on different parameters were compiled and analysed following the analysis of variance (ANOVA) techniques by RCBD design to find out the statistical significance of experimental results. The collected data were analysed by computer package program MSTAT-C software (Russell, 1986). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the influence of cutting management on different cereal crops for assessing their role as dual purpose crop. The results obtained from the study have been presented, discussed and compared in this chapter through tables and figures. The analytical results have been presented in Table 1 through Table 18 and Figure 1 to Figure 14. The possible interpretations are given under the following headings.

4.1 Effect of crop genotype, cutting management and their interactions on growth parameters of cereal crops

4.1.1 Plant height

4.1.1.1 Effect of cutting management

The plant height of cereal crops was significantly influenced by different cutting treatments at 40, 60 and 80 DAS (Table 01). At 40, 60 and 80 DAS, the tallest plant (40.85 cm, 55.87 cm and 105.79 cm, respectively) was recorded from the treatment C_1 (no cut). On the other hand, at 40, 60 and 80 DAS, the short stature plant (35.45 cm, 41.57 cm and 70.52 cm, respectively) was observed in treatment C_3 (two cuts at 25 DAS and 61 DAS). The results obtained from the present study were in conformity with the findings of Pravalika and Gaikwad (2021), Garcia Del Moral *et al.* (1995), Verma (2019), Rahate *et al.* (2019) and Hasan and Shah (2000) who observed reduction in plant height due to different cutting treatments. According to Broumand *et al.* (2010), forage clipping had significant effect on plant height. no clipping of forage had obtained the highest plant height while the lowest stem height was related to forage clipping.

Table 01. Effects of cutting management on plant height (cm) at different dates after sowing

Treatment	Plant height (cm) at		
	40 DAS	**60 DAS**	**80 DAS**
C_1	40.85 a	55.87 a	105.79 a
C_2	40.38 a	45.23 b	88.78 b
C_3	35.45 b	41.57 b	70.52 c
LSD (0.05)	**5.37**	**6.53**	**16.23**
CV (%)	**7.63**	**7.85**	**7.97**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.1.2 Effect of crop genotype

At 40, 60 and 80 DAS, plant height (cm) showed statistically significant variation due to effect of crop genotype (Table 02). Across the genotypes, plant height ranged from 38.05 cm to 44.65 cm at 40 DAS, 46.92 cm to 55.92 cm at 60 DAS and 90.97 cm to 107.19 cm at 80 DAS. Oat (G_4) showed the tallest plant (44.65 cm, 55.92 cm and 107.19 cm) at 40, 60 and 80 DAS, respectively. On the other hand, at 40, 60 and 80 DAS, BARI Barley-1 (G_3) was recorded to have the shortest plant (38.05 cm, 46.92 cm and 90.97 cm, respectively). The results obtained from the present study were similar to the findings of Sharma (2015) who indicated that regeneration capacity of oat was better than barley due to taller plants in oat after applying cutting treatment for fodder. Broumand *et al.* (2010) observed that stem height was significantly influenced by cultivation of different types of cereals.

Table 02. Effects of different crop genotype on plant height (cm) at different dates after sowing

Treatment	Plant height (cm) at		
	40 DAS	**60 DAS**	**80 DAS**
G_1	40.76 a	49.89 a	75.36 a
G_2	38.62 b	48.55 b	99.49 a
G_3	38.05 b	46.92 b	90.97 b
G_4	44.65 a	55.92 a	97.19 a
LSD $_{(0.05)}$	**5.39**	**6.50**	**16.21**
CV (%)	**7.89**	**7.81**	**7.93**

[G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.1.3 Interaction effect of crop genotype and cutting management

Significant interaction effect between the cutting management and different crop genotype was observed on plant height at different dates after sowing in cereal crops (Table 03). At 40 DAS, the tallest plant (46.99 cm) was obtained from the C_1G_4 combination which was statistically similar to C_3G_4 (43.97 cm) and C_2G_4 (42.99 cm). On the other hand, the shortest plant (37.69 cm) at 40 DAS was obtained from the combination C_3G_1, which was statistically similar to C_2G_2 (37.98 cm), C_1G_1 (38.22 cm), C_2G_1 (38.25 cm) and C_3G_2 (38.47 cm) treatment combination. At 60 DAS, the tallest plant (60.57 cm) was obtained from the C_1G_4 combination which was statistically similar to C_3G_1 (55.89 cm), C_3G_4 (57.69 cm), C_1G_1 (56.23 cm), C_1G_3 (55.43 cm) and C_1G_2 (55.30 cm). On the other hand, the shortest plant (47.23 cm) at 60 DAS was obtained from the combination C_3G_3, which was statistically similar to C_2G_2 (53.89 cm) treatment combination. At 80 DAS, the tallest plant (109.40 cm) was obtained from the C_1G_4 combination which was statistically similar to C_1G_2 (104.87 cm) and C_1G_3 (104.67 cm). On the other hand, the shortest plant (79.00 cm) at 80 DAS was obtained from the combination C_3G_4, which was statistically similar to C_3G_2 (81.10 cm) treatment combination. Hemmatzadeh *et al.* (2003) demonstrated the significant interaction effects between clipping and different lines of oat for plant height.

Table 03. Interaction effects of cutting management and different crop genotype on plant height (cm) at different dates after sowing

Treatment combination	**Plant height (cm) at**		
	40 DAS	**60 DAS**	**80 DAS**
C_1G_1	38.22 c	56.23 ab	104.23 abc
C_1G_2	39.41 bc	55.30 ab	104.87 ab
C_1G_3	40.90 bc	55.43 ab	104.67 ab
C_1G_4	46.99 a	60.57 a	109.40 a
C_2G_1	38.25 c	56.54 ab	90.79 bc
C_2G_2	37.98 c	53.89 bc	91.51 bc
C_2G_3	40.13 bc	58.10 a	89.23 bc
C_2G_4	42.99 abc	56.50 ab	88.15 bc
C_3G_1	37.69 c	55.89 a	85.07 bc
C_3G_2	38.47 c	53.47 b	81.10 bc
C_3G_3	41.23 bc	47.23 c	81.97 bc
C_3G_4	43.97 ab	57.69 a	79.00 c
LSD $_{(0.05)}$	**5.39**	**6.52**	**16.21**
CV (%)	**7.89**	**7.88**	**9.80**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.2 Number of tillers m^{-2}

4.1.2.1 Effect of cutting management

No significant variation was observed on the number of tillers m^{-2} of cereal crops at 40 but at 60 DAS and 80 DAS significant data value of number of tillers m^{-2} was recorded due to various cutting treatment (Table 04). At 40, 60 and 80 DAS, numerically the maximum number of tillers m^{-2} (24.58, 75.22 and 67.54) was recorded from treatment C_1 (no cut), while the minimum number of tillers m^{-2} (18.38, 51.90 and 43.98, respectively) was observed from treatment C_3 (two cuts at 25 DAS and 61 DAS). The results mentioned above are in conformity with the findings Hasan and Shah (2000), Jehangir *et al.* (2013), Rahate *et al.* (2019) and Meena *et al.* (2017) who mentioned that number of total tillers were adversely affected by increasing cutting intensity. Broumand *et al.* (2010) recorded that forage clipping had no significant effect on number of tillers at anthesis stage. Hemmatzadeh *et al.* (2003) reported forage clipping had no significant effect on number of tillers.

Table 04. Effects of cutting management on number of tillers m^{-2} at different dates after sowing

Treatment	**Number of tillers m^{-2} at**		
	40 DAS	**60 DAS**	**80 DAS**
C$_1$	24.58	75.22 a	67.54 a
C$_2$	22.08	52.56 b	59.88 a
C$_3$	18.38	51.90 b	43.98 b
LSD $_{(0.05)}$	**NS**	**22.13**	**13.38**
CV (%)	**14.41**	**18.13**	**13.23**

[C$_1$, C$_2$ and C$_3$ indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant]

4.1.2.2 Effect of crop genotype

The result showed that the effect of different crop genotypes of cereal crops on number of tillers m^{-2} was significant at 60 and 80 DAS, but non-significant at 40 DAS (Table 05). Across the genotypes, number of tillers m^{-2} ranged from 15.14 to 29.26 at 40 DAS, 51.58 to 91.67 at 60 DAS and 43.19 to 77.25 at 80 DAS. Oat (G$_4$) was recorded to show the maximum number of tillers m^{-2} (29.26, 91.67 and 77.25) at 40, 60 and 80 DAS, respectively. On the other hand, BARI Gom-33 (G$_1$) showed the minimum number of tillers m^{-2} (15.14, 51.58 and 43.19) at 40, 60 and 80 DAS, respectively. The result corroborates with the findings of Jehangir *et al.* (2013) oat plants with single cut treatment had higher number of tillers m^{-2}. Broumand *et al.* (2010) reported that cultivation of different cereals had significant influence on number of tillers. Hemmatzadeh *et al.* (2003) reported significant differences among five lines of oats in number of tillers.

Table 05. Effects of different crop genotype on number of tillers m^{-2} at different dates after sowing

Treatment	**Number of tillers m^{-2} at**		
	40 DAS	**60 DAS**	**80 DAS**
G_1	15.14	51.58 b	43.19 b
G_2	19.08	55.80 b	44.25 b
G_3	23.23	90.97 a	73.57 a
G_4	29.26	91.67 a	77.25 a
LSD $_{(0.05)}$	**NS**	**22.11**	**13.38**
CV (%)	**11.84**	**18.14**	**13.33**

[G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant.]

4.1.2.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype on number of tillers m^{-2} was non-significant at 40 DAS but exerted significant effect at 60 and 80 DAS in cereal crops (Table 06). At 40 DAS, numerically the maximum number of tillers m^{-2} (34.27) was obtained from the C_1G_4 combination. On the other hand, the minimum number of tillers m^{-2} (14.33) at 40 DAS was obtained from the combination C_2G_1 treatment combination. At 60 DAS, the maximum number of tillers m^{-2} (98.91) was obtained from the C_1G_4 combination, which was statistically similar to C_1G_3 (94.00) and C_2G_4 (93.25). On the other hand, the minimum number of tillers m^{-2} (37.83) at 60 DAS was obtained from the combination C_2G_1 treatment combination. At 80 DAS, the maximum number of tillers m^{-2} (90.26) was obtained from the C_1G_4 combination, which was statistically similar to C_1G_3 (84.00), C_2G_4 (76.71) and C_2G_3 (75.33). On the other hand, the minimum number of tillers m^{-2} (41.08) at

80 DAS was obtained from the combination C_3G_2, which was statistically similar to C_3G_1 (41.67), C_2G_2 (43.00), C_2G_1 (44.67), C_2G_1 (44.67) and C_1G_2 (47.50).

Table 06. Interaction effects of cutting management and different crop genotype on number of tillers m^{-2} at different dates after sowing

Treatment combination	**Number of tillers m^{-2} at**		
	40 DAS	**60 DAS**	**80 DAS**
C_1G_1	15.87	51.08 cd	48.41 d
C_1G_2	16.10	56.90 cd	47.50 d
C_1G_3	32.10	94.00 a	84.00 ab
C_1G_4	34.27	98.91 a	90.26 a
C_2G_1	14.33	37.83 d	44.67 d
C_2G_2	15.07	43.41 d	43.00 d
C_2G_3	16.77	87.75 ab	75.33 abc
C_2G_4	27.33	93.25 a	76.71 abc
C_3G_1	15.23	65.83 bc	41.67 d
C_3G_2	26.07	67.08 bc	41.08 d
C_3G_3	18.67	86.58 ab	64.50 c
C_3G_4	28.33	87.41 ab	68.67 bc
LSD $_{(0.05)}$	**NS**	**22.04**	**13.38**
CV (%)	**11.07**	**18.04**	**13.33**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.3 Number of leaves plant^{-1}

4.1.3.1 Effect of cutting management

Analytical results from the effect of different cutting treatment on leaf area index (LAI) showed non-significant data value at 40 and 60 DAS but returned with significant value at 80 DAS (Table 07). Across the genotypes, number of leaves plant^{-1} ranged from 7.27 to 8.87 at 40 DAS, 12.93 to 14.49 at 60 DAS and 12.11 to 22.27 at 80 DAS. The treatment C_1 (no cut) was recorded to show the maximum number of leaves plant^{-1} (8.87, 14.49 and 22.27) at 40 DAS, 60 DAS and 80 DAS, respectively. On the other hand, the treatment C_3 (two cuts at 25 DAS and 61 DAS) was reported to produce the minimum number of leaves plant^{-1} (7.27, 12.93 and 12.11) at 40, 60 and 80 DAS, respectively. The result corroborates with the findings of AL-dulami and AL-khalifawi (2016) who reported earlier cutting was superior in case of number of leaves in oat. Broumand *et al.* (2010) observed that forage clipping had no significant effect on number of leaves. There was no significant difference in number of leaves at anthesis stage between forage clipping and no clipping of forage.

Table 07. Effects of cutting management on number of leaves plant^{-1} at different dates after sowing

Treatment	**Number of leaves plant^{-1} at**		
	40 DAS	**60 DAS**	**80 DAS**
C_1	8.87	14.49	22.27 a
C_2	8.10	13.50	14.17 a
C_3	7.27	12.93	12.11 b
LSD $_{(0.05)}$	**NS**	**NS**	**9.84**
CV (%)	**11.69**	**15.23**	**16.09**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant]

4.1.3.2 Effect of crop genotype

The result showed that the effect of different crop genotype on number of leaves plant^{-1} was significant at 80 DAS but non-significant at 40 DAS and 60 DAS (Table 8). Across the genotypes, number of leaves plant^{-1} ranged from 7.00 to 9.58 at 40 DAS, 12.94 to 14.49 at 60 DAS and 10.32 to 21.92 at 80 DAS. Oat (G_4) was recorded to show the maximum number of leaves plant^{-1} (9.58, 14.49 and 21.92) at 40 DAS, 60 DAS and 80 DAS, respectively. On the other hand, BARI Gom-33 (G_1) was reported to produce the minimum number of leaves plant^{-1} (7.00 and 10.32) at 40 and 80 DAS, respectively; while BARI Triticale-1 (G_2) showed the minimum number of leaves plant^{-1} (12.94) at 60 DAS. The results are in conformity with the findings of AL-dulami and AL-khalifawi (2016) who reported earlier cutting was superior in case of number of leaves in oat. Broumand *et al.* (2010) observed that the number of leaves at anthesis stage was significantly influenced by cultivation of different cereals.

Table 8. Effects of different crop genotype on number of leaves plant^{-1} at different dates after sowing

Treatment	**Number of leaves plant^{-1} at**		
	40 DAS	**60 DAS**	**80 DAS**
G_1	7.00	12.98	10.32 b
G_2	7.36	12.94	12.80 a
G_3	8.38	14.16	19.69 a
G_4	9.58	14.49	21.92 a
LSD $_{(0.05)}$	**NS**	**NS**	**9.84**
CV (%)	**13.87**	**15.21**	**17.13**

[G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant.]

4.1.3.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype was significant on number of leaves plant^{-1} at different dates after sowing in cereal crops (Table 09). At 40 DAS, the maximum number of leaves plant^{-1} (10.80) was obtained from the C_1G_4 combination which was statistically similar to C_2G_4 (9.60) and C_1G_3 (9.00). On the other hand, the minimum number of leaves plant^{-1} (6.40) at 40 DAS was obtained from the combination C_2G_1, which was statistically similar to C_3G_1 (6.47) treatment combination. At 60 DAS, the interaction effect exerted significant effect on leaves number where the maximum number of leaves plant^{-1} (15.77) was obtained from the C_1G_4 combination, which was statistically similar to C_3G_2 (14.93). On the other hand, the minimum number of leaves plant^{-1} (11.33) at 60 DAS was obtained from the combination C_2G_2. At 80 DAS, the highest number of leaves plant^{-1} (33.27) was obtained from C_1G_4, which was statistically similar to C_1G_3 (28.95). On the other hand, the lowest number of leaves plant^{-1} of cereal crop at 80 DAS (8.13) was recorded from C_3G_1 treatment combination.

Table 09. Interaction effects of cutting management and different crop genotype on number of leaves plant^{-1} at different dates after sowing

Treatment combination	Number of leaves plant^{-1} at		
	40 DAS	60 DAS	80 DAS
C_1G_1	8.13 ab	14.73 abc	12.40 bc
C_1G_2	7.53 b	12.57 abc	14.47 bc
C_1G_3	9.00 ab	14.90 ab	28.95 a
C_1G_4	10.80 a	15.77 a	33.27 a
C_2G_1	6.40 b	11.97 bc	10.41 bc
C_2G_2	7.47 b	11.33 c	13.67 bc
C_2G_3	8.93 ab	14.10 abc	18.13 b
C_2G_4	9.60 ab	14.33 abc	16.73 bc
C_3G_1	6.47 b	12.23 bc	8.13 c
C_3G_2	7.07 b	14.93 ab	10.27 bc
C_3G_3	7.20 b	13.47 abc	12.00 bc
C_3G_4	8.33 ab	13.37 abc	15.77 bc
LSD (0.05)	**3.22**	**3.49**	**9.84**
CV (%)	**13.69**	**15.19**	**16.09**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.4 Leaf area index (LAI)

4.1.4.1 Effect of cutting management

Analytical results from the effect of different cutting treatment on leaf area index (LAI) showed non-significant data value at 40 DAS but returned with significant value at 60 and 80 DAS (Table 10). Across treatments, leaf area index ranged from 1.41 to 1.70 at 40 DAS, 4.14 to 6.83 at 60 DAS and 4.53 to 11.06 at 80 DAS. The treatment C_1 (no cut) was reported to have the maximum leaf area index (1.70, 6.83 and 11.06) at 40, 60 and 80 DAS, respectively. On the other hand, the treatment C_3 (two cuts at 25 DAS and 61 DAS) was observed to have the minimum leaf area index (1.41, 4.14 and 4.53) at 40, 60 and 80 DAS, respectively.

Table 10. Effects of cutting management on leaf area index (LAI) at different dates after sowing

Treatment	**Leaf area index (LAI) at**		
	40 DAS	**60 DAS**	**80 DAS**
C_1	1.70	6.83 a	11.06 a
C_2	1.50	4.68 a	6.80 a
C_3	1.41	4.14 b	4.53 b
LSD $_{(0.05)}$	**NS**	**2.34**	**5.86**
CV (%)	**13.98**	**17.69**	**19.22**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant]

4.1.4.2 Effect of crop genotype

The result showed that the effect of different crop genotype on leaf area index (LAI) was non-significant at 40 DAS but at 60 and 80 DAS, the data were of significant value (Table 11). Across the genotypes, leaf area index ranged from 1.22 to 1.96 at 40 DAS, 2.15 to 8.32 at 60 DAS and 2.53 to 13.86 at 80 DAS. Oat (G_4) showed the maximum leaf area index (1.96, 8.32 and 13.86) at 40, 60 and 80 DAS, respectively. On the other hand, BARI Triticale-1 (G_2) was recorded to produce the minimum leaf area index (1.22 and 2.53) at 40 and 80 DAS, respectively; while BARI Gom-33 (G_1) showed the minimum leaf area index (2.15) at 60 DAS.

Table 11. Effects of different crop genotype on leaf area index (LAI) at different dates after sowing

Treatment	Leaf area index (LAI) at		
	40 DAS	**60 DAS**	**80 DAS**
G_1	1.31	2.15 b	3.29 b
G_2	1.22	2.70 b	2.53 b
G_3	1.66	7.62 a	10.37 a
G_4	1.96	8.32 a	13.86 a
LSD $_{(0.05)}$	**NS**	**2.34**	**5.86**
CV (%)	**13.58**	**17.53**	**23.22**

[G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant.]

4.1.4.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype was significant on leaf area index (LAI) of cereal crops at different dates after sowing (Table 12). At 40 DAS, the highest leaf area index (2.38) was obtained from the C_1G_4 combination. On the other hand, the lowest leaf area index (1.02) at 40 DAS was obtained from the combination C_2G_1. At 60 DAS, the maximum leaf area index (11.05) was obtained from the C_1G_4 combination, which was statistically similar to C_1G_3 (9.49). On the other hand, the minimum leaf area index (1.33) at 60 DAS was obtained from the combination C_3G_2, which was statistically similar to C_2G_1 (1.63) and C_3G_1 (1.63). At 80 DAS, the highest leaf area index (20.75) was obtained from C_1G_4. On the other hand, the lowest leaf area index of cereal crop at 80 DAS (1.45) was recorded from C_3G_2 treatment combination, which was statistically similar to C_1G_2 (3.79), C_2G_1 (2.41), C_2G_2 (2.37) and C_3G_1 (1.92).

Table 12. Interaction effects of cutting management and different crop genotype on Leaf area index (LAI) at different dates after sowing

Treatment combination	Leaf area index (LAI) at		
	40 DAS	60 DAS	80 DAS
C_1G_1	1.52 ab	3.21 f	5.54 c
C_1G_2	1.29 ab	3.57 ef	3.79 d
C_1G_3	1.61 ab	9.49 ab	14.16 b
C_1G_4	2.38 a	11.05 a	20.75 a
C_2G_1	1.02 b	1.63 f	2.41 d
C_2G_2	1.12 b	3.21 f	2.37 d
C_2G_3	1.97 ab	6.16 cd	13.63 b
C_2G_4	1.89 ab	5.59 de	10.23 bc
C_3G_1	1.39 ab	1.63 f	1.92 d
C_3G_2	1.25 ab	1.33 f	1.45 d
C_3G_3	1.52 ab	7.23 bcd	6.74 c
C_3G_4	1.47 ab	8.33 bc	7.21 cd
LSD $_{(0.05)}$	**1.14**	**2.34**	**5.86**
CV (%)	**13.78**	**17.23**	**16.22**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.5 Fresh weight

4.1.5.1 Effect of cutting management

Analytical results from the effect of different cutting treatment on fresh weight of cereal crops (g) showed non-significant data value at 40 and 60 DAS but returned with significant value at 80 DAS (Figure 1). Across treatments, fresh weight ranged from 24.83 g to 27.17 g at 40 DAS, 41.58 g to 50.92 g at 60 DAS and 47.25 g to 101.00 g at 80 DAS. The treatment C_1 (no cut) was reported to have the maximum fresh weight (27.17 g, 50.92 g and 101.00 g) at 40, 60 and 80 DAS, respectively. On the other hand, the treatment C_3 (two cuts at 25 DAS and 61 DAS) was observed to have the minimum fresh weight (24.83 g, 41.58 g and 47.25 g) at 40, 60 and 80 DAS, respectively.

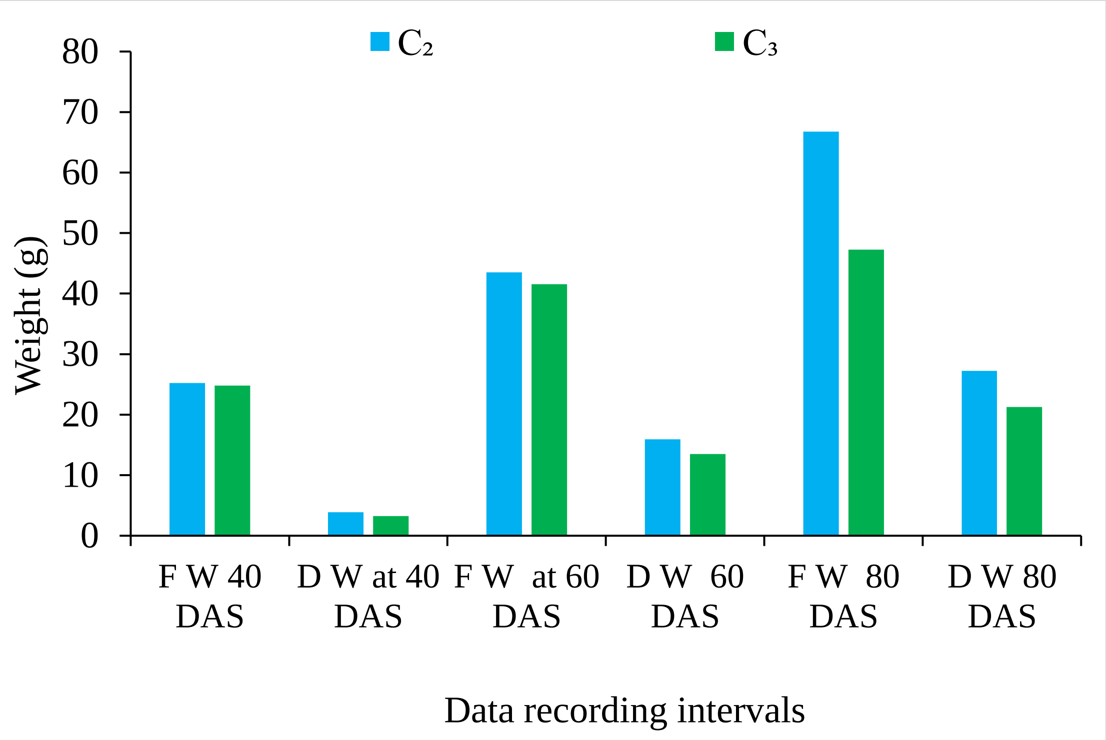

Figure 1. Effect of cutting management on fresh and dry weight of different cereals. [C_2 and C_3 indicate one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 19.12, 2.12, 17.77, 5.73, 31.40 and 10.91 for fresh weight 40 DAS, dry weight 40 DAS, fresh weight 60 DAS, dry weight 60 DAS, fresh weight 80 DAS, dry weight 80 DAS, respectively]

4.1.5.2 Effect of crop genotype

The result showed that the effect of different crop genotype on fresh weight (g) was non-significant at 40 and 60 DAS but showed significant data value at 80 DAS (Figure 2). Across the genotypes, fresh weight ranged from 20.56 g to 31.00 g at 40 DAS, 42.53 g to 49.47 g at 60 DAS and 57.94 g to 90.55 g at 80 DAS. Oat (G_4) was reported to produce numerically the maximum fresh weight (31.00 g, 49.47 g and 90.55 g) at 40, 60 and 80 DAS, respectively. On the other hand, BARI Gom-33 (G_1) was recorded to produce numerically the minimum fresh weight (20.56 g, 42.53 g and 57.94 g) at 40, 60 and 80 DAS, respectively.

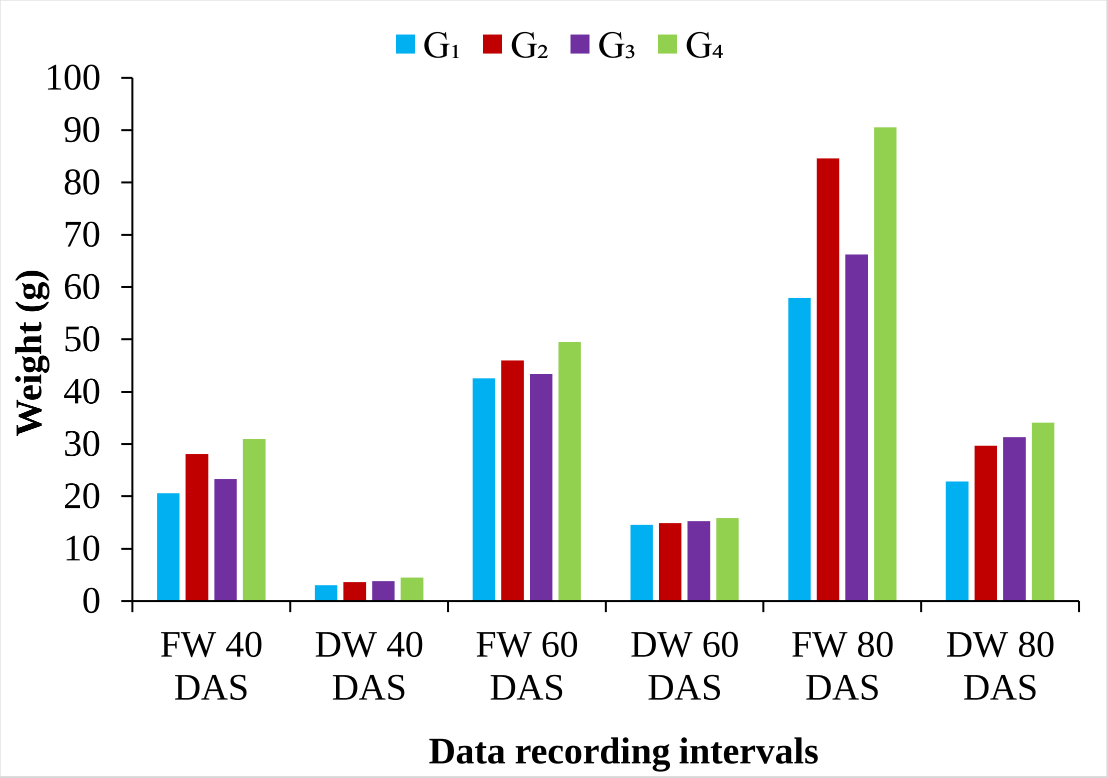

Figure 2. Effect of crop genotype on fresh and dry weight of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) = 19.13, 2.11, 17.71, 5.71, 31.39 and 10.93 for fresh weight 40 DAS, dry weight 40 DAS, fresh weight 60 DAS, dry weight 60 DAS, fresh weight 80 DAS, dry weight 80 DAS, respectively]

4.1.5.3 Interaction effect of crop genotype and cutting management

Fresh weight of cereal crops (g) was significantly influenced by the interaction of cutting management and different crop genotype at different dates after sowing (Table 13). The maximum fresh weight (38.67 g) at 40 DAS was obtained from C_1G_4 treatment combination while the minimum fresh weight (14.67 g) was recorded from C_3G_1 treatment combination. At 60 DAS, the maximum fresh weight (54.10 g) was observed from C_1G_4 treatment combination which was statistically similar to C_1G_1 (52.70 g), C_1G_2 (53.00 g) and C_1G_3 (52.57 g). On the other hand, the minimum fresh weight (30.97 g) was recorded from C_3G_1 treatment combination. At 80 DAS, the maximum fresh weight (126.67 g) was obtained from C_1G_4 treatment combination which was statistically similar to C_1G_2 (112.67 g). On the other hand, the minimum fresh weight of cereal crop (45.67 g) was recorded from C_3G_3 treatment combination.

Table 13. Interaction effects of cutting management and different crop genotype on fresh weight (g) at different dates after sowing

Treatment combination	Fresh weight (g) at		
	40 DAS	60 DAS	80 DAS
C_1G_1	24.83 ab	52.70 a	72.33 bc
C_1G_2	30.17 ab	53.00 a	112.67 ab
C_1G_3	27.83 ab	52.57 a	78.33 cd
C_1G_4	38.67 a	54.10 a	126.67 a
C_2G_1	22.17 ab	43.93 ab	55.83 cde
C_2G_2	29.83 ab	45.93 ab	64.25 cde
C_2G_3	26.17 ab	42.37 ab	74.71 cde
C_2G_4	21.67 ab	45.40 ab	72.33 cde
C_3G_1	14.67 b	30.97 b	45.67 de
C_3G_2	24.33 ab	38.97 ab	53.00 cde
C_3G_3	26.50 ab	41.73 ab	45.67 e
C_3G_4	22.17 ab	42.27 ab	62.67 cde
LSD (0.05)	**19.40**	**17.77**	**31.44**
CV (%)	**14.71**	**13.25**	**13.85**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.1.6 Dry weight

4.1.6.1 Effect of cutting management

The result showed that the effect of different cutting treatment on dry matter weight cereal crops (g) was non-significant at 40 and 60 DAS but returned with significant value at 80 DAS (Figure 1). Across treatments, dry matter weight ranged from 3.27 g to 4.08 g at 40 DAS, 13.52 g to 16.01 g at 60 DAS and 21.24

g to 39.41 g at 80 DAS. The treatment C_1 (no cut) was reported to have the maximum dry matter weight (4.08 g, 16.01 g and 39.41 g) at 40, 60 and 80 DAS, respectively. On the other hand, the treatment C_3 (two cuts at 25 DAS and 61 DAS) was observed to have the minimum dry matter weight (3.27 g, 13.52 g and 21.24 g) at 40, 60 and 80 DAS, respectively.

4.1.6.2 Effect of crop genotype

The result showed that the effect of different crop genotype on dry matter weight (g) was non-significant at 40 and 60 DAS but returned with significant value at 80 DAS (Figure 2). Across the genotypes, dry matter weight ranged from 3.00 g to 4.49 g at 40 DAS, 14.60 g to 15.86 g at 60 DAS and 22.82 g to 34.12 g at 80 DAS. Oat (G_4) was reported to produce numerically the maximum dry matter weight (4.49 g, 15.86 g and 34.12 g) at 40, 60 and 80 DAS, respectively. On the other hand, BARI Gom-33 (G_1) was recorded to produce numerically the minimum dry matter weight (3.00 g, 14.60 g and 22.82 g) at 40, 60 and 80 DAS, respectively.

4.1.6.3 Interaction effect of crop genotype and cutting management

Dry matter weight of cereal crops (g) was significantly influenced at 40 and 80 DAS but showed non-significant values at 60 DAS by the interaction of cutting management and different crop genotype (Table 14). The maximum dry matter weight (5.55 g) at 40 DAS was obtained from C_1G_4 treatment combination while the minimum dry matter weight (2.64 g) was recorded from C_3G_1 treatment combination. At 60 DAS, numerically the maximum dry matter weight (17.23 g) was observed from C_1G_4 treatment combination whereas, the minimum dry matter weight (12.13 g) was recorded from C_3G_2 treatment combination. At 80 DAS, the maximum dry matter weight (47.36 g) was obtained from C_1G_4 treatment combination which was statistically similar to C_1G_2 (43.20 g). On the other hand, the minimum dry matter weight of cereal crop (20.23 g) was recorded from C_3G_1 treatment combination.

Table 14. Interaction effects of cutting management and different crop genotype on dry weight (g) at different dates after sowing

Treatment combination	Dry weight (g) at		
	40 DAS	60 DAS	80 DAS
C_1G_1	4.45 ab	16.66	27.23 ab
C_1G_2	4.11 ab	15.43	43.20 a
C_1G_3	3.60 ab	16.10	39.86 ab
C_1G_4	5.55 a	17.23	47.36 a
C_2G_1	4.35 ab	16.83	21.00 de
C_2G_2	3.81 ab	14.90	20.64 de
C_2G_3	3.92 ab	14.00	31.33 bcd
C_2G_4	3.03 b	15.83	32.23 bc
C_3G_1	2.64 b	15.00	20.23 e
C_3G_2	3.29 b	12.13	25.25 cde
C_3G_3	3.39 b	14.60	22.57 cde
C_3G_4	2.67 b	13.03	22.77 de
LSD (0.05)	**2.12**	**NS**	**10.91**
CV (%)	**23.67**	**12.45**	**11.23**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD. NS indicate Non-significant.]

4.2 Effect of crop genotype, cutting management and their interactions on yield contributing parameters of cereal crops

4.2.1 Number of grains spike^{-1}

4.2.1.1 Effect of cutting management

The number of grains spike^{-1} data did showed significant variation due to effect of different cutting treatments (Figure 3). The treatment C_1 (no cut) was recorded to have the maximum number of grains spike^{-1} (54.42) whereas the minimum was 40.96 from treatment C_3 (two cuts at 25 DAS and 61 DAS) which indicated that treatment C_1 (no cut) showed 32.86% more grains spike^{-1} over treatment C_3 (two cuts at 25 DAS and 61 DAS). The result was in contrary with the findings of Verma (2019) who mentioned grains spike^{-1} was not significantly affected due to cutting treatments. Malik and Babli (2017) observed grains spike^{-1} decreased with increase in cut for fodder. Broumand *et al.* (2010) mentioned that the effect of forage clipping on number of grains spike^{-1} was significant. The highest number of grains spike^{-1} was related to no clipping of forage and the lowest one was obtained by forage clipping. Arif *et al.* (2006) mentioned higher number of grains spike^{-1} in no-cut treatment.

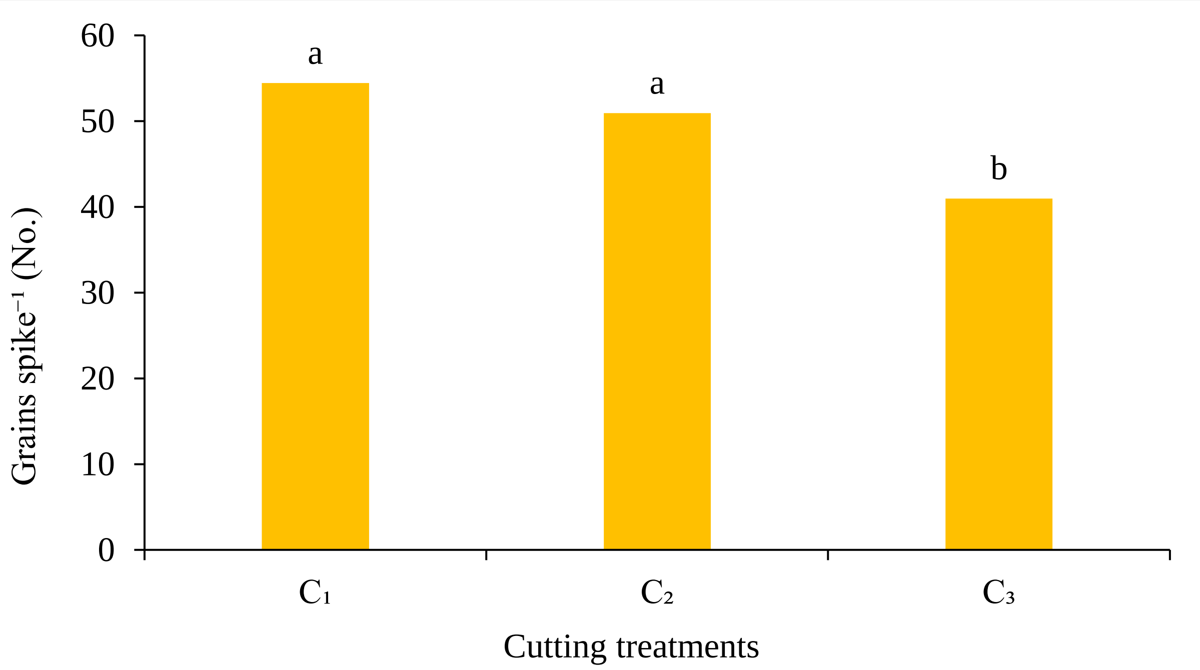

Figure 3. Effect of cutting management on number of grains spike^{-1} of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 13.75]

4.2.1.2 Effect of crop genotype

The number of grains spike^{-1} data showed significant variation due to different crop genotypes of cereal crops (Figure 4). Oat (G_4) was reported to have maximum number of grains spike^{-1} (56.66) whereas the minimum was 40.67

from BARI Barley-1 (G_3) which indicated that Oat had 39.31% higher number of grains spike^{-1} over BARI Barley-1. Broumand *et al.* (2010) reported that the number of grains in spike was significantly influenced by cultivation of different cereals.

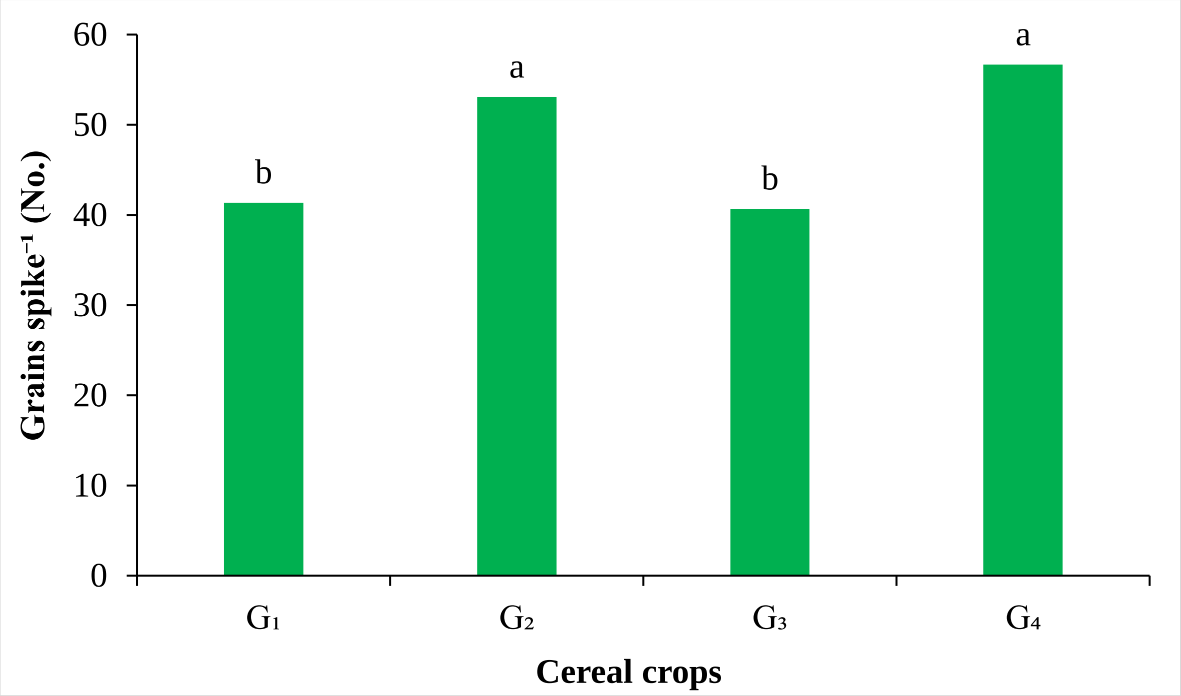

Figure 4. Effect of crop genotype on number of grains spike^{-1} of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) = 13.77]

4.2.1.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype was significant on number of grains spike^{-1} at harvest in cereals (Table 15). The maximum number of grains spike^{-1} (63.33) was obtained from the C_1G_4 combination which was statistically similar to C_1G_2 (58.60), C_2G_2 (57.07), C_2G_4 (55.80), C_1G_1 (50.13) and C_3G_2 (43.58). On the other hand, the minimum number of grains spike^{-1} (33.93) was obtained from the combination C_3G_1, which was statistically similar to C_3G_3 (35.47) treatment combination. Treatment C_1G_4 combination showed 86.64% higher number of grains spike^{-1} compare with treatment combination C_3G_1.

Table 15. Interaction effects of cutting management and different crop genotype on yield attributes

Treatment combination	Number of grains spike^{-1}	Number of unfilled grains spike^{-1}	Weight of grains spike^{-1} (g)	Spike length (cm)
C_1G_1	50.13 abc	3.27	3.15 a	14.81 bc
C_1G_2	58.60 ab	3.33	3.15 a	15.17 bc
C_1G_3	45.60 bc	3.20	2.85 b	16.81 b
C_1G_4	63.33 a	2.27	4.75 a	28.67 a
C_2G_1	40.00 bc	2.80	2.58 ab	13.51 bc
C_2G_2	57.07 abc	2.93	2.15 a	14.30 c
C_2G_3	40.95 bc	2.60	1.27 b	15.75 bc
C_2G_4	55.80 abc	2.60	2.63 ab	26.71 a
C_3G_1	33.93 c	3.20	1.58 b	12.67 bc
C_3G_2	43.58 abc	3.13	1.87 ab	13.34 bc
C_3G_3	35.47 c	2.33	1.17 b	14.29 bc
C_3G_4	50.87 bc	2.20	2.50 ab	25.35 a
LSD $_{(0.05)}$	**13.79**	**1.41**	**1.52**	**2.45**
CV (%)	**16.08**	**28.73**	**37.58**	**8.02**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. NS indicate Non-significant.]

4.2.2 Number of unfilled grains spike^{-1}

4.2.2.1 Effect of cutting management

The number of unfilled grains spike^{-1} showed non-significant data due to variation among cutting treatments on cereal crops (Figure 5). The treatment C_1 (no cut) resulted in numerically the maximum number of unfilled grains spike^{-1} (3.01) whereas the minimum number of unfilled grains spike^{-1} (2.72) was observed from the treatment C_3 (two cuts at 25 DAS and 61 DAS). C_3 (two cuts at 25 DAS and 61 DAS) treatment showed 10.66% fewer number of unfilled grains spike^{-1} than C_1 (no cut).

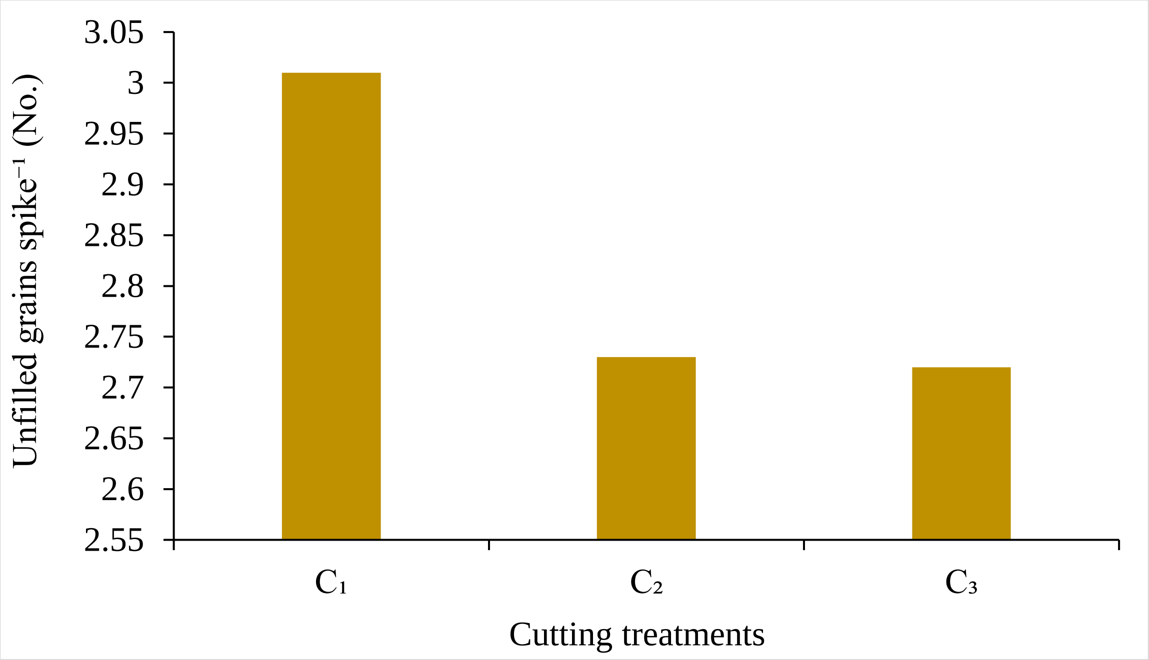

Figure 5. Effect of cutting management on number of unfilled grains spike^{-1} of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 1.41]

4.2.2.2 Effect of crop genotype

The number of unfilled grains spike^{-1} showed non-significant data due to variation among the crop genotype of different cereals (Figure 6). Numerically, BARI Triticale-1 (G_2) was recorded to produce the maximum number of unfilled grains spike^{-1} (3.18) whereas the minimum number of unfilled grains spike^{-1} (2.35) was observed from Oat (G_4). Oat showed 35.31% fewer number of unfilled grains spike^{-1} than BARI Triticale-1.

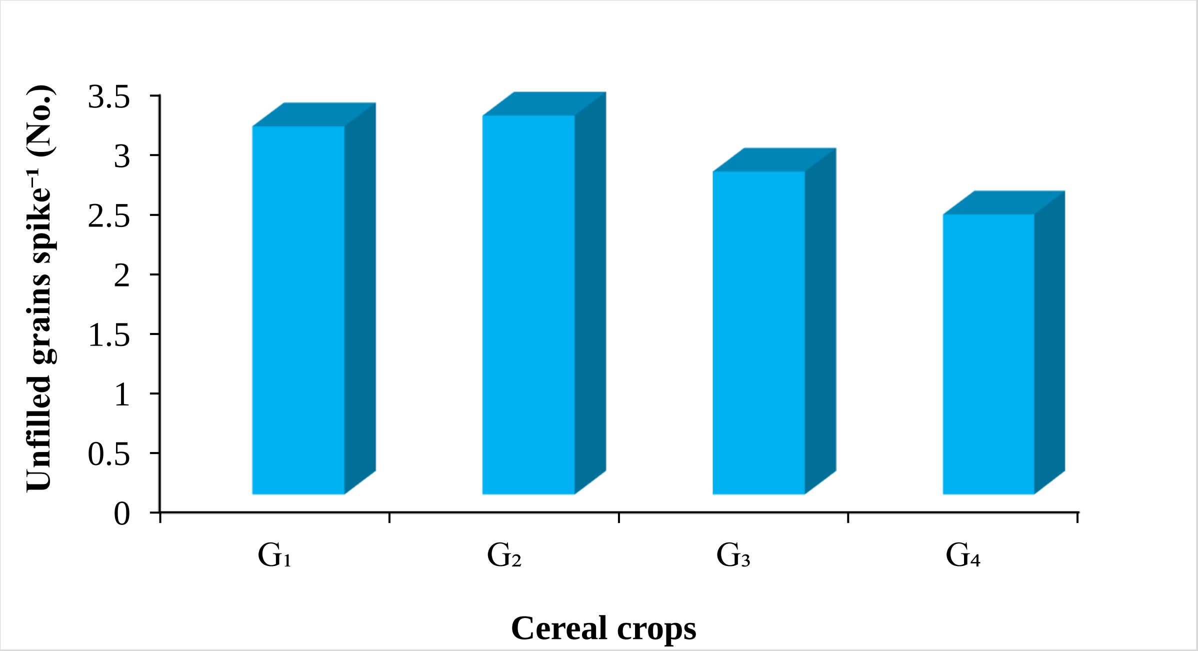

Figure 6. Effect of crop genotype on number of unfilled grains spike^{-1} of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) =1.41]

4.2.2.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype was non-significant on number of unfilled grains spike^{-1} at harvest in cereals (Table 15). Numerically, the maximum number of unfilled grains spike^{-1} (3.33) was obtained from the C_1G_2 combination. On the other hand, numerically the minimum number of unfilled grains spike^{-1} (2.20) was obtained from the combination C_3G_4. Treatment C_3G_4 combination showed 51.36% fewer number of unfilled grains spike^{-1} compare with treatment combination C_1G_2.

4.2.3 Weight of grains spike^{-1}

4.2.3.1 Effect of cutting management

Weight of grains spike^{-1} showed significant variation due to the effect of different cutting management on cereal crops (Figure 7). The C_1 (no cut) was recorded to have the maximum weight of grains spike^{-1} (3.49 g). On the other hand, the minimum weight of grains spike^{-1} (1.81 g) was obtained from treatment

C_3 (two cuts at 25 DAS and 61 DAS). It can be inferred from the result that C_1 (no cut) showed 92.81% heavier seed than C_3 (two cuts at 25 DAS and 61 DAS).

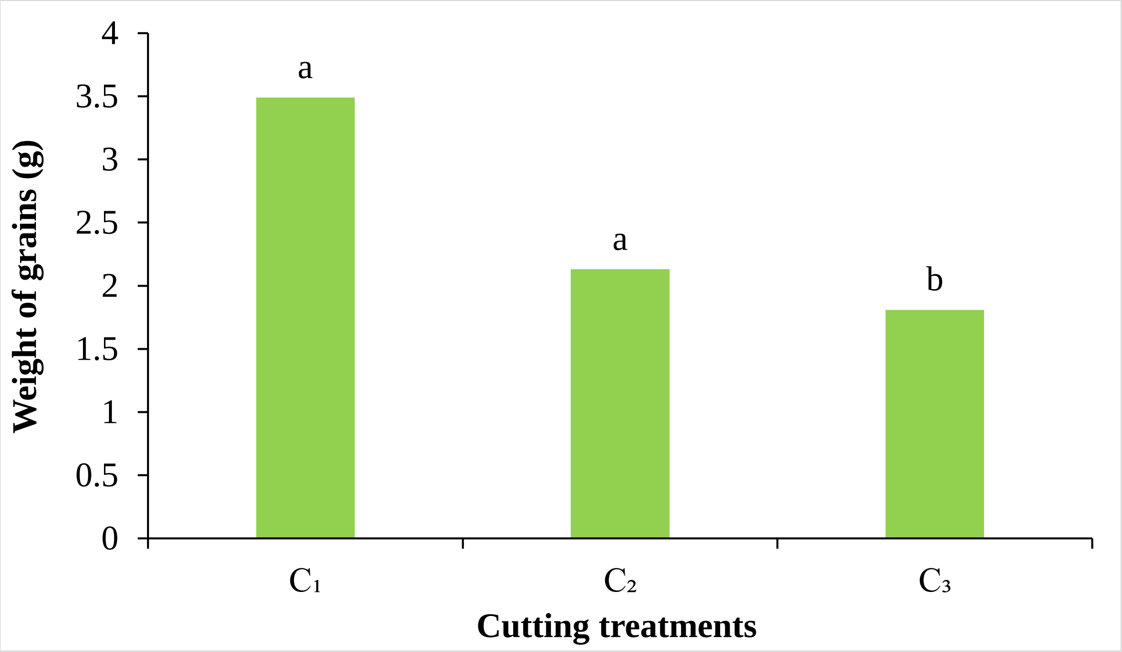

Figure 7. Effect of cutting management on weight of grains spike^{-1} of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 1.52]

4.2.3.2 Effect of crop genotype

Weight of grains spike^{-1} showed significant variation among the crop genotype of different cereals (Figure 8). Oat (G_4) showed the maximum weight of grains spike^{-1} (3.29 g), which was statistically similar to BARI Gom-33 (G_1) (2.43 g) and BARI Triticale-1 (G_2) (2.39 cm). On the other hand, the minimum weight of grains spike^{-1} (1.76 g) was obtained from BARI Barley-1 (G_3). It can be inferred from the result that Oat showed 86.93% heavier grains spike^{-1} than BARI Barley-1. The results mentioned above are in conformity with the findings of Salama *et al.* (2021) who also mention weight of grains was significantly affected due to different cereal crops.

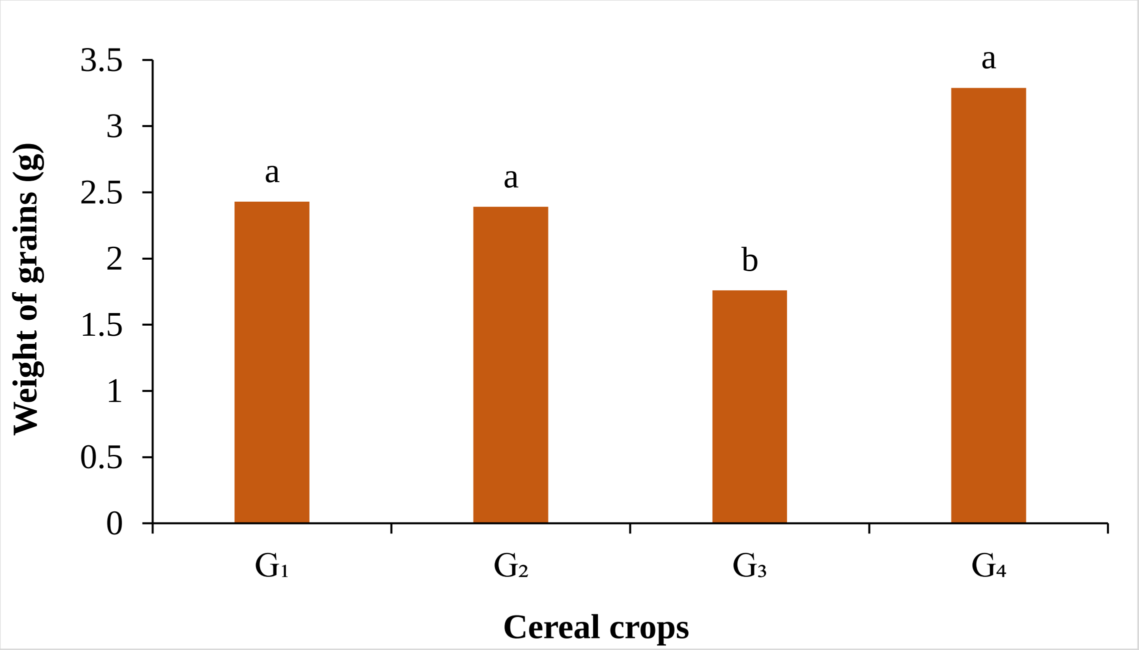

Figure 8. Effect of crop genotype on weight of grains spike^{-1} of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) = 1.52]

4.2.3.3 Interaction effect of crop genotype and cutting management

Interaction effect of cutting management and different crop genotype had significant influence on weight of grains spike^{-1} of cereals (Table 15). The result of the investigation showed that, the treatment combination C_1G_4 was recorded to show the highest weight of grains spike^{-1} (4.75 g), which was statistically similar to C_1G_1 (3.15 g), C_1G_2 (3.15 g) and C_2G_2 (2.15 g). On the other hand, the treatment combination C_3G_3 was reported to have the lowest weight of grains spike^{-1} (1.17 g), which was statistically similar to treatment combination C_2G_3 (1.27 g) and C_3G_2 (1.87 g). Treatment C_1G_4 combination showed 305.98% heavier grains spike^{-1} compare with treatment combination C_3G_3.

4.2.4 Spike length

4.2.4.1 Effect of cutting management

Spike length of cereal crops is an important yield determining parameters. The result revealed that the effect of cutting treatments on spike length was statistically significant (Figure 9). The treatment C_1 (no cut) was recorded to have the maximum length of panicle (18.87 cm) whereas the treatment C_3 (two cuts at 25 DAS and 61 DAS) showed the minimum length of panicle (16.41 cm). The result opposed with the findings of Verma (2019) who also mentioned that cut treatment did not exert any significant effect on spike length of barley.

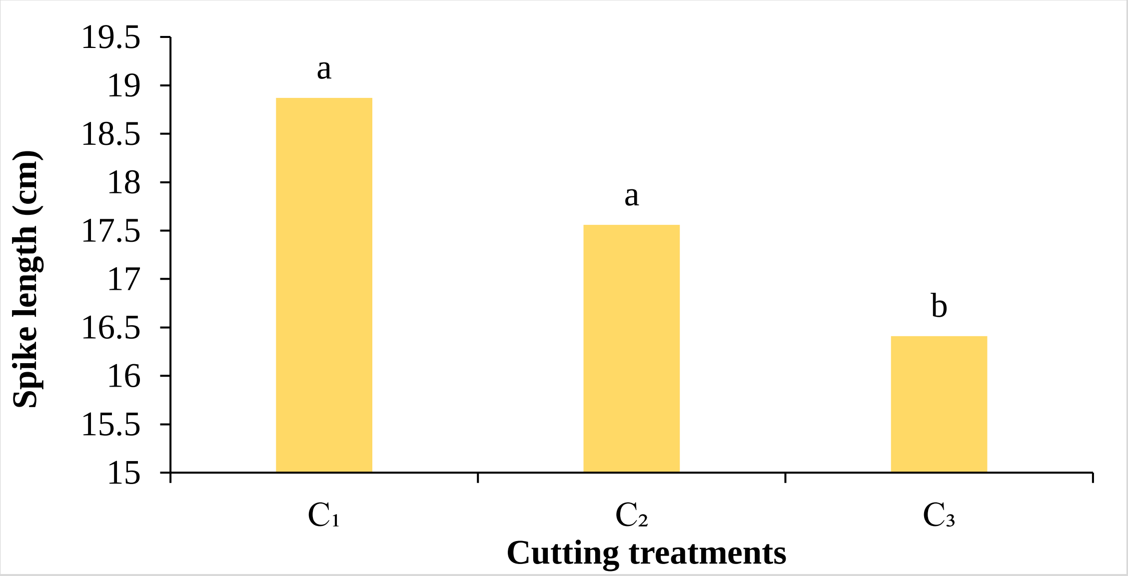

Figure 9. Effect of cutting management on spike length of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 2.45]

4.2.4.2 Effect of crop genotype

Spike length of cereal crop is a yield determining character. The result revealed that the effect of crop genotype on spike length was statistically significant (Figure 10). Oat (G_4) was recorded to produce the longest spike (26.91 cm) whereas BARI Gom-33 (G_1) was reported to produce the shortest spike (13.66 cm), which was statistically similar to BARI Triticale-1 (G_2) (14.27 cm) and BARI Barley-1 (G_3) (15.61 cm). The results revealed that Oat (G_4) showed 96.99% longer spike over BARI Gom-33 (G_1).

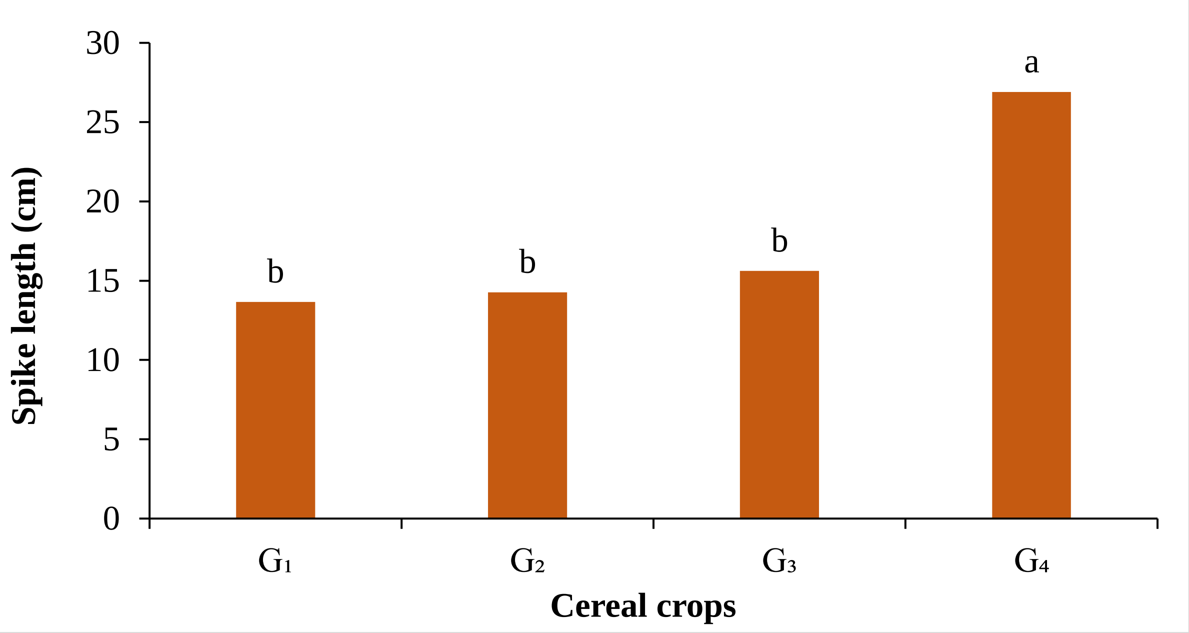

Figure 10. Effect of crop genotype on spike length of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) = 2.45]

4.2.4.3 Interaction effect of crop genotype and cutting management

Spike length of cereal is a yield determining parameters. The result revealed that the interaction effect of cutting management and different crop genotype on spike length was statistically significant (Table 15). The treatment combination C_1G_4 was recorded to show the maximum length of spike (28.67 cm) which was statistically similar to C_2G_4 (26.71 cm) and C_3G_4 (25.35 cm) combination. On the other hand, the treatment combination C_2G_2 was reported to have the minimum length of spike (14.30 cm). Treatment C_1G_4 combination showed 100.48% longer spike compare with treatment combination C_2G_2.

4.3 Effect of crop genotype, cutting management and their interactions on yield parameters and harvest index of cereal crops

4.3.1 Grain yield

4.3.1.1 Effect of cutting management

Grain yield (t ha^{-1}) of cereal crops showed significant data due to variation among the different cutting management (Figure 11). Significantly the highest grain yield (5.25 t ha^{-1}) was recorded from treatment C_1 (no cut) and the lowest grain yield (3.80 t ha^{-1}) was recorded from treatment C_3 (two cuts at 25 DAS and 61 DAS). The result revealed that treatment C_1 (no cut) out yielded over treatment C_3 (two cuts at 25 DAS and 61 DAS) by producing 38.15% higher grain yield, which may perhaps be due to the higher yield attributes in C_1 (no cut). Broumand *et al.* (2010) stated that grain yield was significantly influenced by forage clipping. The maximum grain yield was related to no clipping of forage and the lowest one was obtained by forage clipping. The results mentioned above are in contrary with the findings of Hu *et al.* (2019), Bisht *et al.* (2008), Poysa (1985), Salama (2019), Singh *et al.* (2017), Kharub *et al.* (2013) and Malik and Babli (2017) who observed non-significant effect of cutting management on grain yield of different dual-purpose cereal crops.

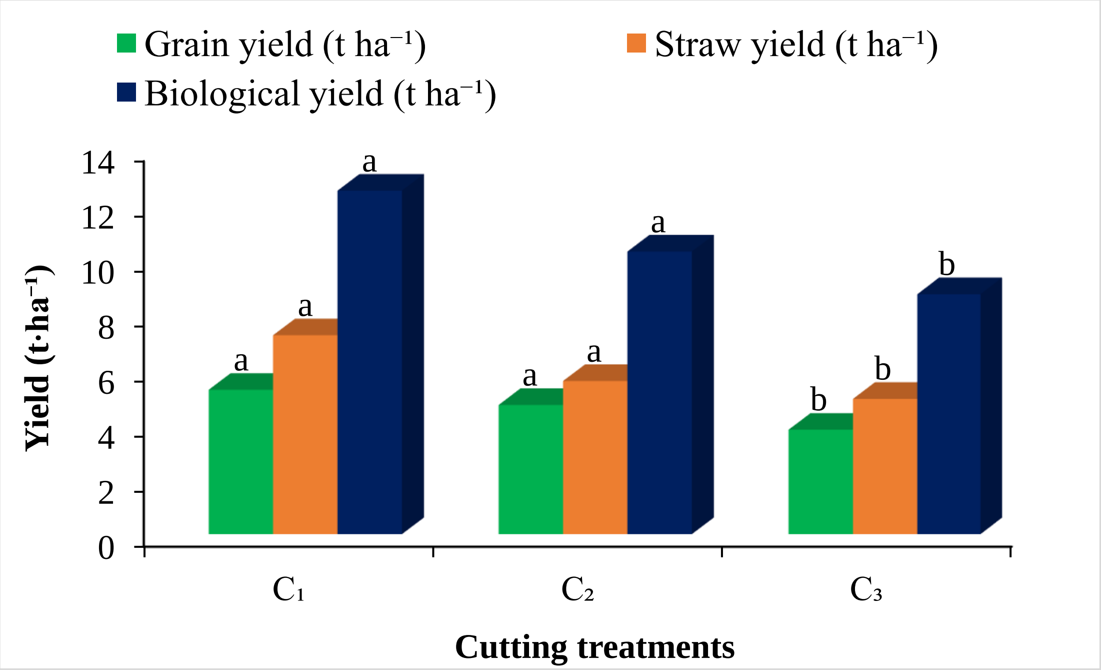

Figure 11. Effect of cutting management on grain, straw and biological yield of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 1.43, 2.27 and 3.51 for grain, straw and biological yield, respectively]

4.3.1.2 Effect of crop genotype

Grains yield (t ha^{-1}) of cereal crops showed significant data due to variation among the genotypes (Figure 12). The highest grain yield (5.60 t ha^{-1}) was recorded from oat (G_4) which was statistically similar to BARI Barley-1 (G_3) (4.80 t ha^{-1}). On the other hand, the lowest grain yield (3.81 t ha^{-1}) was recorded from BARI Gom-33 (G_1). The result revealed that oat out yielded over BARI Gom-33 by producing 46.98% higher yield, which may perhaps due to the higher yield attributing parameters in oat. The result corroborates with the findings of Andrews *et al.* (1991) who mentioned oat and triticale providing higher grain yield over other cereal crops which could be due to the inherent genetic makeup of these crops.

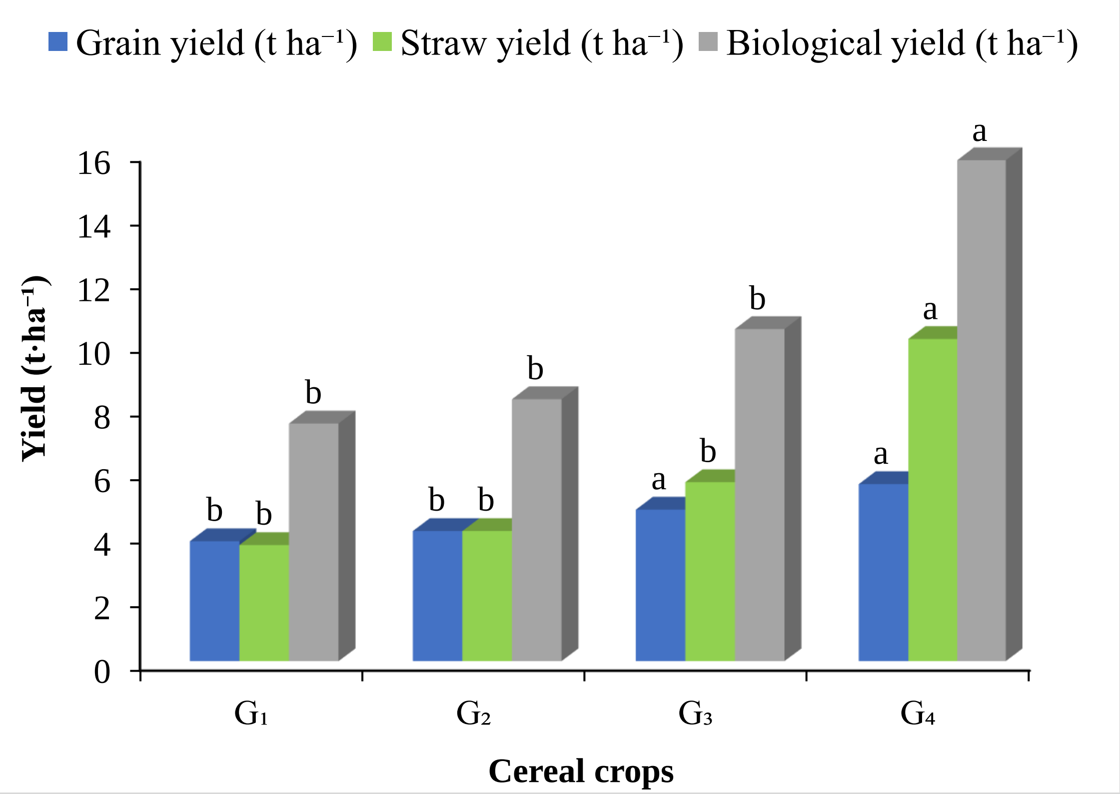

Figure 12. Effect of crop genotype on grain, straw and biological yield of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) =1.42, 2.26 and 3.52 for grain, straw and biological yield, respectively]

4.3.1.3 Interaction effect of crop genotype and cutting management

Interaction effect between the cutting management and different crop genotype was significant on grain yield of cereal crops (Table 16). The maximum grain yield (6.25 t ha^{-1}) was obtained from the treatment C_1G_4 combination, which was statistically similar to C_2G_4 (5.85 t ha^{-1}). On the other hand, the minimum grain yield (3.15 t ha^{-1}) was obtained from the C_3G_1 combination, which was statistically similar to C_3G_2 (3.30 t ha^{-1}), C_2G_1 (3.86 t ha^{-1}) and C_1G_1 (4.41 t ha^{-1}) and. Treatment C_1G_4 combination showed 98.41% higher grains yield compare with treatment combination C_3G_1.

Table 16. Interaction effects of cutting management and different crop genotype on yields and harvest index

Treatment combination	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
C_1G_1	4.41 cde	4.58 c	8.99 def	49.05 abc
C_1G_2	5.07 abcd	4.61 c	9.68 cdef	52.37 ab
C_1G_3	5.25 abc	7.16 b	12.41 bcd	42.30 de
C_1G_4	6.25 a	12.57 a	18.82 a	33.21 g
C_2G_1	3.86 cde	3.42 c	7.28 ef	53.02 a
C_2G_2	4.03 bcde	4.41 c	8.44 ef	47.75 bc
C_2G_3	5.07 abc	5.09 bc	10.16 cde	49.90 abc
C_2G_4	5.85 a	9.37 b	15.22 b	38.43 ef
C_3G_1	3.15 e	3.07 c	6.22 f	50.64 abc
C_3G_2	3.30 de	3.36 c	6.66 ef	49.55 abc
C_3G_3	4.09 bcde	4.75 bc	8.84 ef	46.27 cd
C_3G_4	4.67 ab	8.51 b	13.18 bc	35.43 fg
LSD (0.05)	**1.43**	**2.28**	**3.55**	**4.98**
CV (%)	**18.54**	**21.35**	**19.25**	**6.56**

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. Mean was calculated from three replicates for each treatment and significance of values were tested at $p \leq 0.05$ applying LSD.]

4.3.2 Straw yield

4.3.2.1 Effect of cutting management

Different cereal crops straw yield (t ha^{-1}) varied significantly for cutting treatment shown in Figure 11. The maximum straw yield (7.23 t ha^{-1}) was recorded from treatment C_1 (no cut). On the other hand, the lowest straw yield (4.92 t ha^{-1}) was obtained from treatment C_3 (two cuts at 25 DAS and 61 DAS). The findings from the experimental work of Bisht *et al.* (2008) who mention that cutting treatment did not have significant effect on straw yield opposed to the results of this study. Broumand *et al.* (2010) found significant difference between forage clipping and no clipping of forage regarding straw yield. The highest straw yield was related to no clipping of forage and the lowest one was achieved by forage clipping.

4.3.2.2 Effect of crop genotype

Straw yield (t ha^{-1}) varied significantly for different crops genotype shown in Figure 12. The maximum straw yield (10.15 t ha^{-1}) was recorded from oat (G_4). On the other hand, the minimum straw yield (3.69 t ha^{-1}) was recorded from BARI Gom-33 (G_1). Broumand *et al.* (2010) reported cultivation of different cereals had significant effects on straw yield. Fontaneli *et al.* (2009) concluded that wheat, barley and triticale producing equivalent forage yields to those obtained with black oats pasture.

4.3.2.3 Interaction effect of crop genotype and cutting management

Straw yield differed significantly due to interaction effect between cutting management and different crop genotype (Table 16). The highest straw yield (12.57 t ha^{-1}) was obtained from the C_1G_4 combination. On the other hand, the lowest straw yield (3.07 t ha^{-1}) was obtained from the combination of C_3G_1, which was statistically similar to C_3G_2 (3.36 t ha^{-1}), C_2G_1 (3.42 t ha^{-1}), C_2G_2 (4.41 t ha^{-1}), C_1G_1 (4.58 t ha^{-1}) and C_1G_2 (4.61 t ha^{-1}). Treatment C_1G_4 combination showed 309.44% higher straw yield compare with treatment combination C_3G_1.

4.3.3 Biological yield

4.3.3.1 Effect of cutting management

The biological yield (t ha^{-1}) showed significant variation due to different cutting management (Figure 11). It was observed that treatment C_1 (no cut) showed significantly the highest biological yield (12.48 t ha^{-1}) and the lowest biological yield (8.72 t ha^{-1}) was recorded from treatment C_3 (two cuts at 25 DAS and 61

DAS). Ghandi and Aminpour (2004) reported that forage clipping decreased biological yield.

4.3.3.2 Effect of crop genotype

The biological yield (t ha^{-1}) showed significant variation due to different crop genotype (Figure 12). It was observed that oat (G_4) produced the maximum biological yield (15.75 t ha^{-1}) and the minimum biological yield (7.50 t ha^{-1}) was recorded from BARI Gom-33 (G_1). The results mentioned above are in conformity with the findings of Sharma (2015) who also reported oat having higher amount of biological yield over other cereal crops which might be attributed to the genetic makeup of oat.

4.3.3.3 Interaction effect of crop genotype and cutting management

Biological yield was influenced significantly by the interaction effect of cutting management and different crop genotype (Table 16). The highest biological yield (18.82 t ha^{-1}) was obtained from the C_1G_4 combination. On the other hand, the lowest biological yield (6.22 t ha^{-1}) was obtained from the combination of C_3G_1, which was statistically similar to C_1G_1 (8.99 t ha^{-1}), C_2G_1 (7.28 t ha^{-1}), C_2G_2 (8.44 t ha^{-1}), C_3G_2 (6.66 t ha^{-1}) and C_3G_3 (8.84 t ha^{-1}). Treatment C_1G_4 combination showed 202.57% higher biomass compare with treatment combination C_3G_1.

4.3.4 Harvest index

4.3.4.1 Effect of cutting management

Numeral difference among cutting management exerted non-significant variation on harvest index (Figure 13). The treatment C_2 (one cut at 25 DAS) showed the highest value for harvest index (45.76%) whereas, the lowest harvest index (42.06%) was recorded from the treatment C_1 (no cut). The results mentioned above are in conformity with the findings Hu *et al.* (2019) who observed higher value of harvest indices in single cut over no-cut applied on cereal crops. The results of this study were supported by the findings of Broumand *et al.* (2010) who reported that harvest index was not significantly influenced by forage clipping. The maximum harvest index was obtained by forage clipping and the minimum one was related to no clipping of forage.

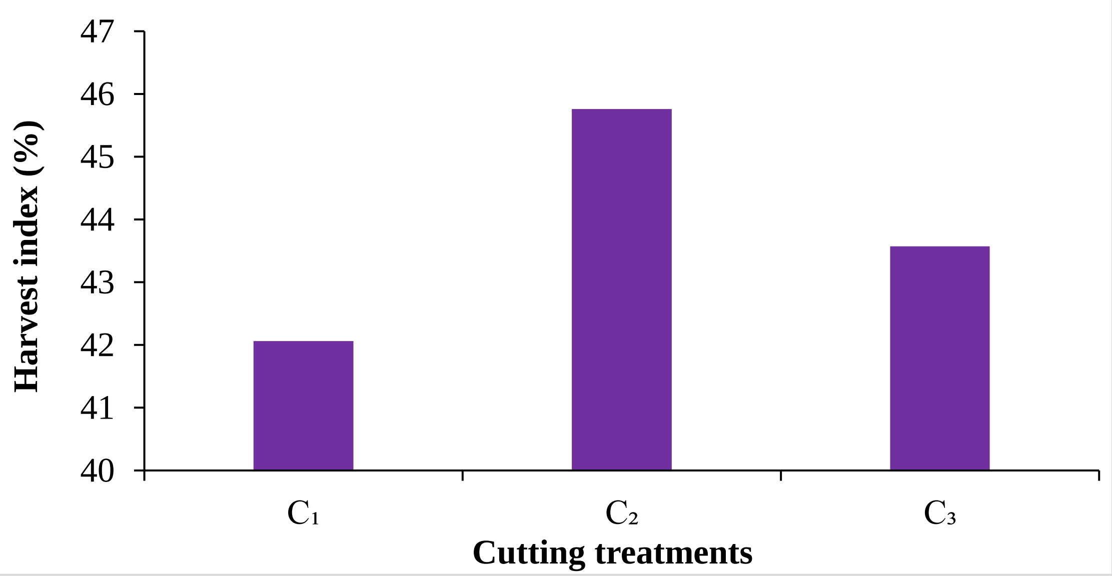

Figure 13. Effect of cutting management on harvest index of different cereals. [C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. LSD (0.05) = 4.97]

4.3.4.2 Effect of crop genotype

Genotypic difference exerted significant variation on harvest index (Figure 14). BARI Gom-33 (G_1) showed the highest harvest index (50.80%) whereas, the lowest harvest index (35.50%) was recorded from Oat (G_4). The results corroborate with the findings of Broumand *et al.* (2010) who reported that harvest index was significantly influenced by cereals cultivation.

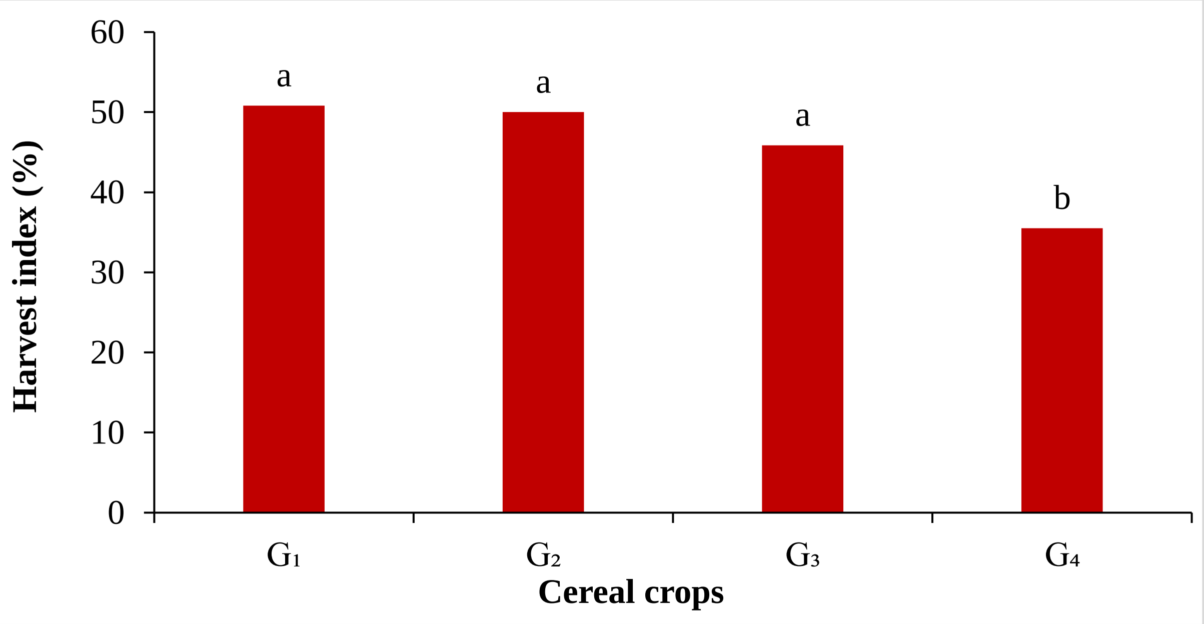

Figure 14. Effect of crop genotype on harvest index of different cereals. [G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively. LSD (0.05) = 5.03]

4.3.4.3 Interaction effect of crop genotype and cutting management

Harvest index was significantly influenced by the interaction effect of cutting management and different crop genotype (Table 16). The maximum harvest index (53.02%) was obtained from the treatment combination C_2G_1, which was statistically similar to C_1G_2 (52.37%), C_3G_1 (50.64%) and C_2G_3 (49.90%). On the other hand, the minimum harvest index (33.21%) was obtained from the C_1G_4 combination.

4.4 Difference in grain yield due to the application of different cutting treatments over control/no cut treatment

A comparative performance of grain yield of cereal crops due to cutting treatment over the no cut plots has been presented in tabular form in Table 17. The yield hectare^{-1} for cereal crops ranged from 3.15 t (C_3G_1) to 6.25 t (C_1G_4).

Table 17. Difference in grain yield due to the application of different cutting treatments over control/no cut treatment

Cereal crops genotype	Cutting management	Seed yield (t ha^{-1})	Yield difference over control treatment (%)
G_1	**C_1**	4.41	0.00
	C_2	3.86	−12.47
	C_3	3.15	−28.57
G_2	**C_1**	5.07	0.00
	C_2	4.03	−20.51
	C_3	3.30	−34.91
G_3	**C_1**	5.25	0.00
	C_2	5.07	−3.43
	C_3	4.09	−22.09
G_4	**C_1**	6.25	0.00
	C_2	5.85	−6.40
	C_3	4.67	−25.28

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively.]

$$\left[\text{Yield difference over no-cut (\%)} = \frac{\text{(Seed yield with cut - seed yield at no cut)}}{\text{Seed yield at no cut}} \times 100\right]$$

The yield reduction for single and double cut over no cut treatment ranged from 3.43% (C_2G_3) to 34.91% (C_3G_2). All the cereal crops showed reduction in grain yield due to cutting treatment. Between the cutting treatments, double cut tends to produce lower percentage of grain yield of all the cereal crops over single cut under this study.

4.5 Fodder production from different cutting management

4.5.1 Fresh fodder weight

Double cut applied plot returned with higher amount of fresh fodder than single cut applied plot (Table 18). In case of single cut, oat tends to produce the highest amount of fresh weight of fodder (263.17 $g \cdot m^{-2}$) compare to other cereal crops, while the lowest amount of fresh weight of fodder (166.50 $g \cdot m^{-2}$) was recorded from BARI Gom-33 (wheat). Similarly, in case of double cut, the maximum amount of fresh weight of fodder was recorded from oat (796.67 $g \cdot m^{-2}$) while BARI Gom-33 (wheat) returned with the minimum amount of fresh fodder weight (581.00 $g \cdot m^{-2}$). The results obtained from the present study were similar to the findings of Arif *et al.* (2019), AL-dulami and AL-khalifawi (2016), Jha *et al.* (2016), Malik and Babli (2017), Jehangir *et al.* (2013) and Hasan and Shah (2000) who observed higher amount of fresh fodder with multiple cutting than single cut applied on cereal crops.

Table 18. Amount of fodder production from different cutting management in 1 m^2 area

Treatment combination	Fresh fodder weight m^{-2} (g)	Dry fodder weight m^{-2} (g)
C_2G_1	166.50	30.33
C_2G_2	209.83	31.62
C_2G_3	198.00	25.50
C_2G_4	263.17	33.94
C_3G_1	581.00	68.19
C_3G_2	746.50	69.90
C_3G_3	609.50	44.14
C_3G_4	796.67	56.74

[C_1, C_2 and C_3 indicate no cut, one cut at 25 DAS and two cuts at 25 DAS and 61 DAS, respectively. G_1, G_2, G_3 and G_4 indicate Wheat, Triticale, Barley and Oat, respectively.]

4.5.2 Dry fodder weight

Double cut applied plot returned with higher amount of dry weight of fodder than single cut applied plot (Table 18) In case of single cut, oat tends to produce the highest amount of dry weight of fodder (33.94 g·m^{-2}) compare to other cereal crops, while the lowest amount of dry weight of fodder (25.50 g·m^{-2}) was recorded from BARI Barley-1 (barley). On the other hand, in case of double cut, the maximum amount of dry fodder was recorded from BARI Triticale-1 (69.90 g·m^{-2}) while BARI Barley-1 (barley) returned with the minimum amount of dry weight of fodder (44.14 g·m^{-2}). The results obtained from the present study were in conformity with the findings of Arif *et al.* (2019), AL-dulami and AL-khalifawi (2016), Kaur *et al.* (2013), Pravalika and Gaikwad (2021), Sheoran *et al.* (2018), Malik and Babli (2017), Jehangir *et al.* (2013), Kumar (2012), Hasan and Shah (2000) and Satpal *et al.* (2019) who observed higher amount of dry fodder with multiple cutting than single cut applied on cereal crops.

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted at the research field of the department of agronomy, Sher-e-Bangla Agricultural University during the period from November, 2019 to March, 2020 for assessing different cereal crops in dual purpose influenced by cutting management. The experiment comprised of two factors viz. factor A: Cereal crops genotype (4), i) G_1 = Wheat (BARI Gom-33), ii) G_2 = Triticale (BARI Triticale-1), iii) G_3 = Barley (BARI Barley-1) and iv) G_4 = Oat; factor B: Cutting management (3); i) C_1 = Uncut, ii) C_2 = One cut at 25 DAS and iii) C_3 = Two cut at 25 DAS and 61 DAS. This experiment was laid out in a randomized complete block design (RCBD) with three replications. Data were collected on different aspects of growth, yield attributes and yield of cereal crops.

Significant differences were observed among different cutting management with respect to yield and yield attributing parameters of cereal crops. A yield advantages of 0.55 t ha^{-1} and 1.45 t ha^{-1} over C_2 (One cut at 25 DAS) and C_3 (Two cut at 25 DAS and 61 DAS) applied plot, respectively was found which was possibly aided by the tallest plant at 80 DAS (105.79 cm), the highest number of tillers m^{-2} (67.54), the maximum number of leaves plant^{-1} at 80 DAS (22.27), maximum leaf area index at 80 DAS (11.06), the highest fresh weight at 80 DAS (101.00 g), highest dry weight at 80 DAS (39.41 g), the maximum number of grains spike^{-1} (54.42), the highest weight of grains spike^{-1} (3.49 g), the longest spike (18.87 cm), the highest straw yield (7.23 t ha^{-1}) and the highest biological yield (12.48 t ha^{-1}) in the C_1 (No cut) treatment. On the other hand, treatment C_2 (One cut at 25 DAS) gave similar result C_1 treatment in some parameters like—plant height, number of tillers m^{-2}, number of tillers plant^{-1}, leaf area index, number of grains spike^{-1}, weight of grains spike^{-1}, spike length, straw yield, biological yield and harvest index.

The result revealed that oat (G_4) exhibited its superiority to other tested cereal crop BARI Triticale-1 (G_2) and BARI Barley-1 (G_3) in terms of seed yield, the former out-yielded over BARI Triticale-1 (G_2) and BARI Barley-1 (G_3) by 35.59% and 16.00% higher yield, respectively. Oat (G_4) also showed the tallest plant at 80 DAS (107.19 cm), the highest number of tillers m^{-2} (77.25), the maximum number of leaves $plant^{-1}$ at 80 DAS (21.92), maximum leaf area index at 80 DAS (13.86), the highest fresh weight at 80 DAS (90.55 g), the highest dry weight at 80 DAS (34.12 g), the maximum number of grains $spike^{-1}$ (56.66), the lowest number of unfilled grains $spike^{-1}$ (2.35), the highest weight of grains $spike^{-1}$ (3.29 g), the longest spike (26.91 cm), the highest straw yield (10.15 t ha^{-1}) and the highest biological yield (15.75 t ha^{-1}) than other tested cereal crops in this experiment. On the other hand, BARI Gom-33 (G_1) returned with 46.98% lower grain yield than Oat (G_4) which was numerically the lowest compare with other cereal crops under study.

Interaction results of cutting management and different crop genotype indicated that all the studied parameters were influenced significantly. The highest grain yield (6.25 t ha^{-1}) was found in C_1G_4 (No cut × Oat) interaction due to the tallest plant at 80 DAS (109.40 cm), the highest number of tillers m^{-2} (90.26), the maximum number of leaves $plant^{-1}$ at 80 DAS (33.27), maximum leaf area index at 80 DAS (20.75), the highest fresh weight at 80 DAS (126.67 g), the highest dry weight at 80 DAS (47.36 g), lower number of unfilled grains $spike^{-1}$ (2.27), the highest weight of grains $spike^{-1}$ (4.75 g) and the longest spike (28.67 cm) production with significantly the highest value of straw yield (12.57 t ha^{-1}) and biological yield (18.82 t ha^{-1}). It was also observed that C_2G_4 combination (One cut at 25 DAS × Oat) showed the second highest grain yield (5.85 t ha^{-1}) aided by higher number of grains $spike^{-1}$ (55.80), higher weight of grains $spike^{-1}$ (2.63 g), longer spike (26.71 cm), higher straw yield (9.37 t ha^{-1}) and biological yield (15.22 t ha^{-1}).

The yield reduction for single and double cut over no cut treatment ranged from 3.43% (C_2G_3) to 34.91% (C_3G_2). All the cereal crops showed reduction in grain yield due to cutting treatment. Between the cutting treatments, double cut tends to produce lower percentage of grain yield of all the cereal crops over single cut under this study. Double cut applied plot returned with higher amount of fresh and dry fodder than single cut applied plot. Regarding fresh weight of fodder with single cut and double cut, oat tends to produce the highest amount of fresh weight of fodder (263.17 and 796.67 $g \cdot m^{-2}$, respectively) compare to other cereal crops. Regarding dry fodder weight, with single cut, oat tends to produce the highest amount of dry weight of fodder (33.94 $g \cdot m^{-2}$) whereas in case of double cut, the maximum amount of dry fodder was recorded from BARI Triticale-1 (69.90 $g \cdot m^{-2}$).

CONCLUSION

Fodder production along with dairy cattle rearing is a highly profitable enterprise now a day for many small-scale farm households in Bangladesh to increase their income and to accumulate assets. Farmers are turning towards fodder production from cereal crops as fodder brought high profit to their household income. Fodder and feed scarcity, which is marked in the lean season, is a major factor limiting milk production on small-scale dairy farms in this country. Finding fodder technologies that complement current cropping patterns, practices and needs for feed with acceptable changes in inputs and risks are keys to satisfying the aspirations of many resource-poor Bangladeshis. From the above result it was revealed that C_1 (No cut) and G_4 (oat) gave higher yield along with higher values in most of the yield attributes. Among the cutting treatments, two cuts at 25 DAS and 61 DAS was high yielder with higher amount of fresh and dry fodder production than other cutting treatments. Among the interactions, C_1G_4 and C_2G_4 were superior in most of the growth, yield attributes and fodder production along with grain yield. Interaction of C_2G_4 (One cut at 25 DAS × Oat) performed the best in respect of yield attributes and yield parameters including grain yield along with higher amount of fodder production. From the result of the experiment, it may be concluded that oat cut once at 25 DAS seemed promising as dual-purpose crop in Bangladesh.

RECOMMENDATION

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

- More major and minor cereal crops may be used with different number of cutting management for getting cereal crop specific cutting frequency recommendation.
- 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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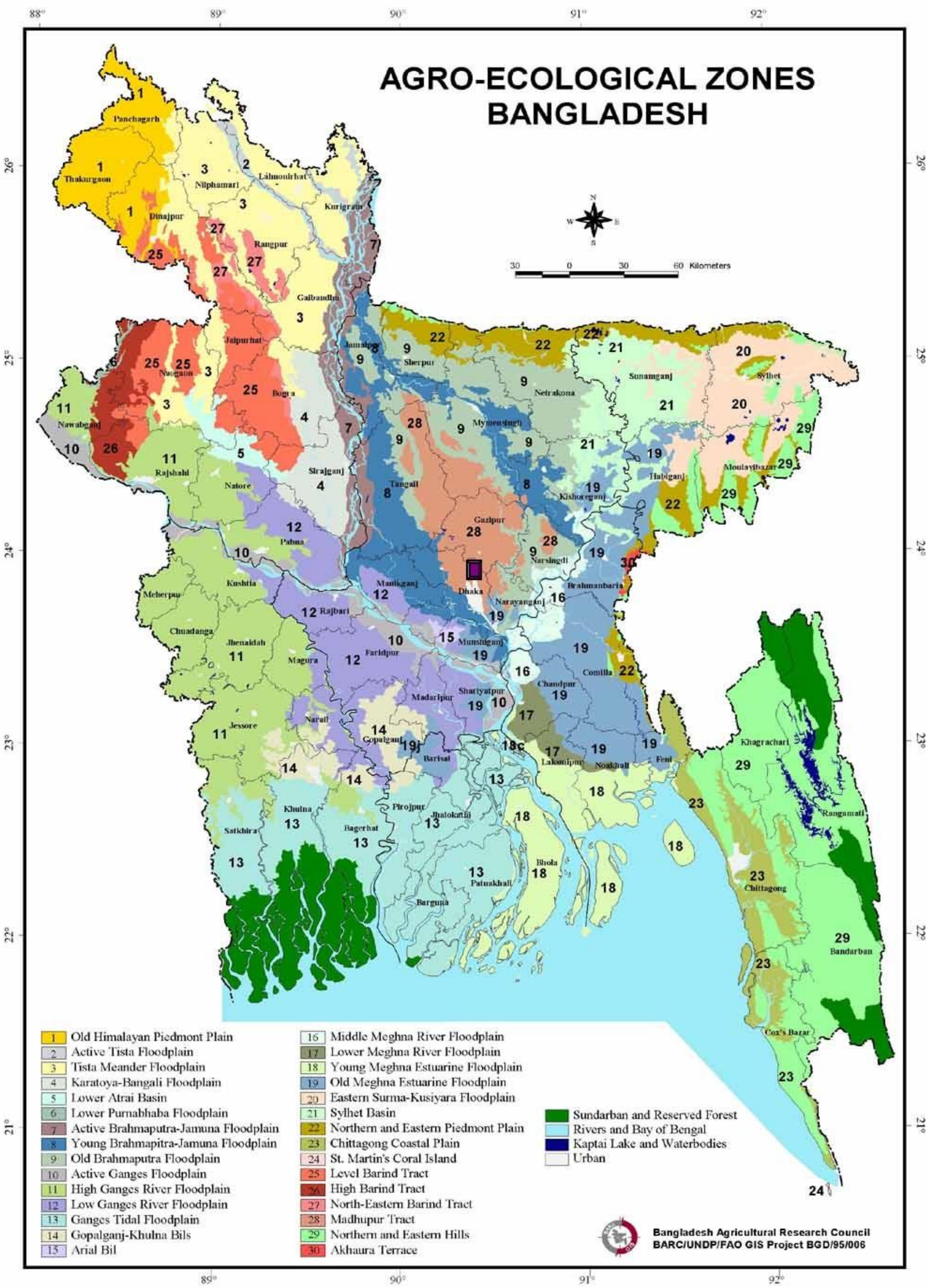
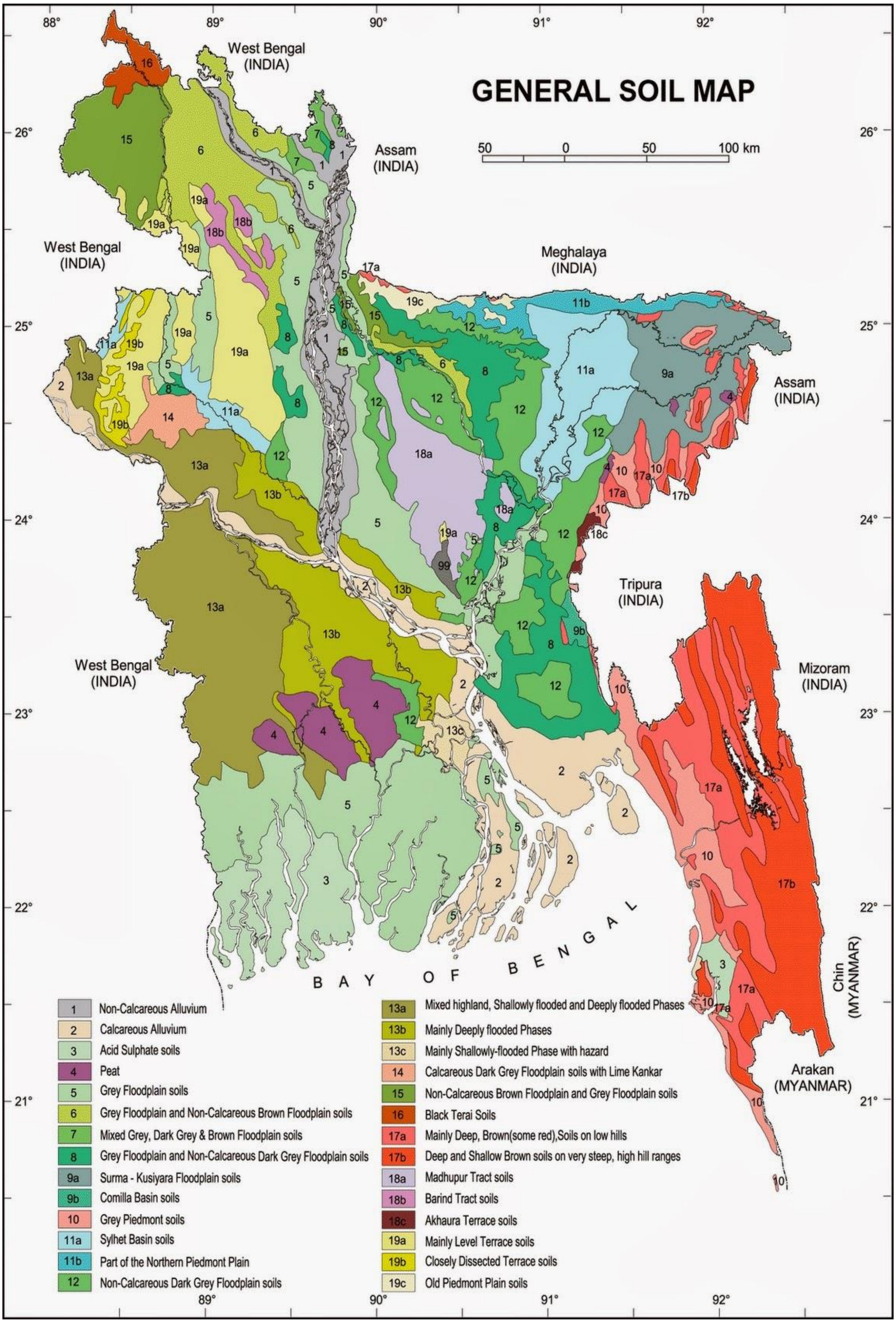
APPENDICES

Appendix I (A). Map showing the experimental sites under study



■ **The experimental site under study**

Appendix I (B). Map showing the general soil sites under study



Appendix II. Characteristics of soil of experimental site is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

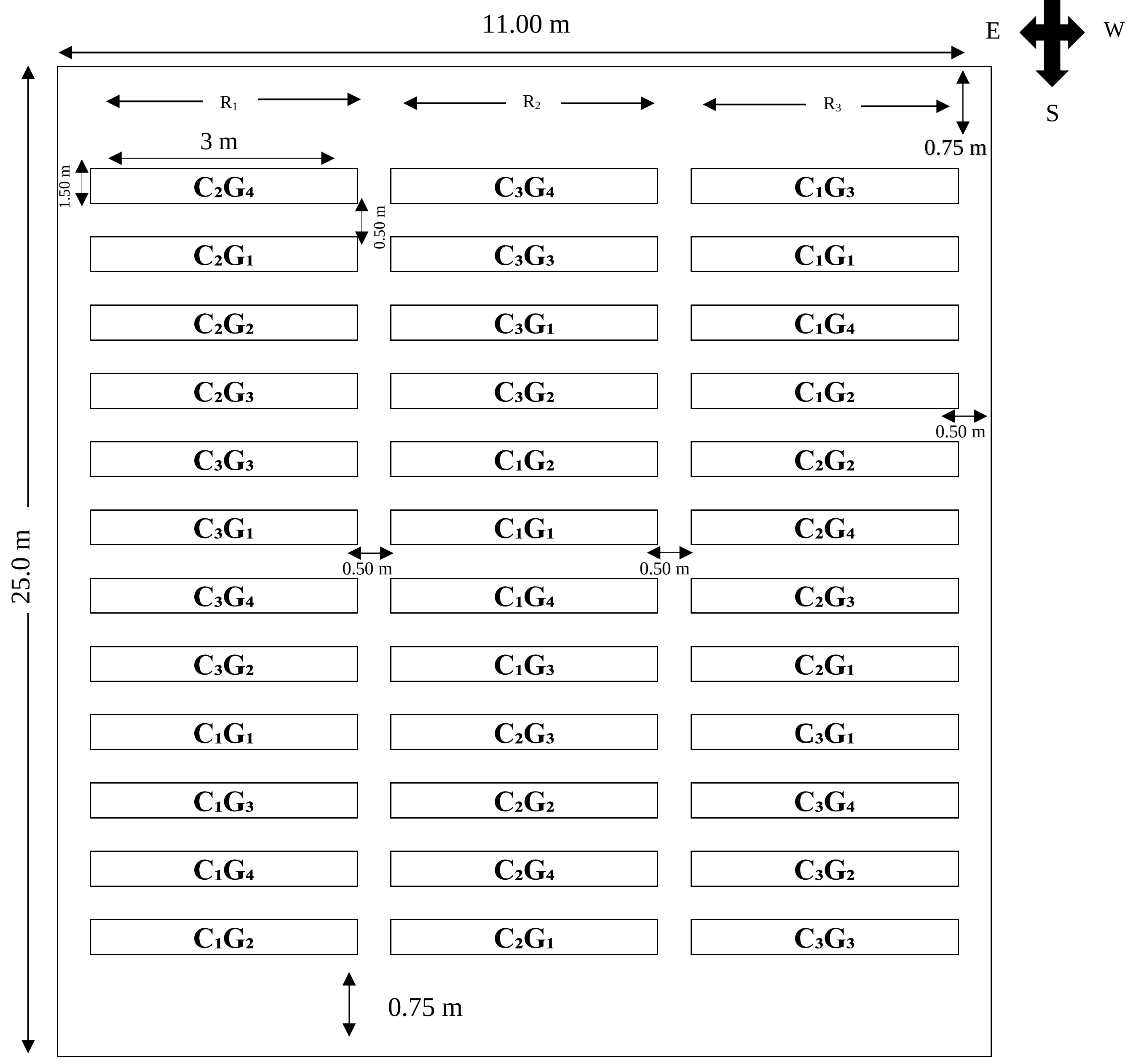
Morphological features	**Characteristics**
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro–Aman–Boro

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.5
Organic carbon (%)	0.43
Organic matter (%)	0.75
Total N (%)	0.075
Available P (ppm)	21.00
Exchangeable K (meq/ 100 g soil)	0.11
Available S (ppm)	43

Source: SRDI, 2018

Appendix III. Field layout of the two-factor experiment in Randomized Complete Block Design (RCBD)



R_1	R_2	R_3
C_2G_4	C_3G_4	C_1G_3
C_2G_1	C_3G_3	C_1G_1
C_2G_2	C_3G_1	C_1G_4
C_2G_3	C_3G_2	C_1G_2
C_3G_3	C_1G_2	C_2G_2
C_3G_1	C_1G_1	C_2G_4
C_3G_4	C_1G_4	C_2G_3
C_3G_2	C_1G_3	C_2G_1
C_1G_1	C_2G_3	C_3G_1
C_1G_3	C_2G_2	C_3G_4
C_1G_4	C_2G_4	C_3G_2
C_1G_2	C_2G_1	C_3G_3

Number of treatment combinations = 12
Plot spacing: = 0.50 m
Between replication = 0.50 m

Factor A: Cutting management (3)	**Factor B:** Cereal crops genotype (4)
Uncut - C_1	Wheat - G_1
One cut at 25 DAS - C_2	Triticale - G_2
Two cuts at 25 DAS and 61 DAS - C_3	Barley - G_3
	Oat - G_4

Appendix IV: Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from November 2019 to March 2020

Year	Month	Temperature			Relative Humidity (%)	Rainfall (mm)	Sunshine (Hour)
		Max (°C)	Min (°C)	Mean (°C)			
2019	**November**	32	24	29	65	42.8	349
	December	27	19	24	53	1.4	372
2020	**January**	27	18	23	50	3.9	364
	February	30	19	26	38	3.1	340
	March	35	24	31	38	19.6	353

Appendix V. Analysis of variance (mean square) of plant height of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Plant height at 40 DAS	Plant height at 60 DAS	Plant height at 80 DAS
Cutting management	2	0.914 ^{NS}	1409.836*	758.923 ^{NS}
Cereal crops	3	80.503*	26.912 ^{NS}	10.715 ^{NS}
Cutting management × Cereal crops	6	4.989*	28.733*	30.354*
Error	24	0.017	0.017	0.017
Total	35	7.819	87.806	49.501

* indicates significant at 5% level of probability
NS = Non-significant

Appendix VI. Analysis of variance (mean square) of Number of tillers m^{-2} of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Number of tillers m^{-2} at 40 DAS	**Number of tillers m^{-2} at 60 DAS**	**Number of tillers m^{-2} at 80 DAS**
Cutting management	2	117.050^{NS}	905.890^{NS}	114.479^{NS}
Cereal crops	3	327.861^{NS}	4274.943*	3034.697*
Cutting management × Cereal crops	6	96.999^{NS}	94.315*	134.458*
Error	24	0.017	0.017	0.017
Total	35	51.431	434.369	289.720

* indicates significant at 5% level of probability
NS = Non-significant

Appendix VII. Analysis of variance (mean square) of Number of leaves $plant^{-1}$ of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Number of leaves $plant^{-1}$ at 40 DAS	**Number of leaves $plant^{-1}$ at 60 DAS**	**Number of leaves $plant^{-1}$ at 80 DAS**
Cutting management	2	7.684^{NS}	7.466^{NS}	346.178*
Cereal crops	3	12.070^{NS}	5.726^{NS}	273.382*
Cutting management × Cereal crops	6	1.030*	5.162*	64.549*
Error	24	0.017	0.017	0.017
Total	35	1.662	1.814	54.291

* indicates significant at 5% level of probability
NS = Non-significant

Appendix VIII. Analysis of variance (mean square) of Leaf area index (LAI) of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Leaf area index (LAI) at 40 DAS	Leaf area index (LAI) at 60 DAS	Leaf area index (LAI) at 80 DAS
Cutting management	2	0.268 ^{NS}	24.550*	126.564*
Cereal crops	3	1.029 ^{NS}	93.384*	273.365*
Cutting management × Cereal crops	6	0.219*	4.450*	22.720*
Error	24	0.017	0.017	0.017
Total	35	0.153	10.182	34.570

* indicates significant at 5% level of probability
NS = Non-significant

Appendix IX. Analysis of variance (mean square) of Fresh weight of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Fresh weight at 40 DAS	Fresh weight at 60 DAS	Fresh weight at 80 DAS
Cutting management	2	18.583 ^{NS}	292.142 ^{NS}	6351.619*
Cereal crops	3	197.880 ^{NS}	87.843 ^{NS}	1277.108 ^{NS}
Cutting management × Cereal crops	6	82.935*	120.021*	481.670*
Error	24	0.017	0.017	0.017
Total	35	32.252	44.810	555.000

* indicates significant at 5% level of probability
NS = Non-significant

Appendix X. Analysis of variance (mean square) of Dry weight of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of		
		Dry weight at 40 DAS	Dry weight at 60 DAS	Dry weight at 80 DAS
Cutting management	2	2.148 ^{NS}	23.954 ^{NS}	1219.258*
Cereal crops	3	3.378 ^{NS}	2.609 ^{NS}	62.428 ^{NS}
Cutting management × Cereal crops	6	1.346*	3.818 ^{NS}	30.306*
Error	24	0.017	0.017	0.017
Total	35	0.655	2.259	80.230

* indicates significant at 5% level of probability
NS = Non-significant

Appendix XI. Analysis of variance (mean square) of Number of tillers plant^{-1} of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of	
		Number of tillers plant^{-1} at 40 DAS	Number of tillers plant^{-1} at 60 DAS
Cutting management	2	0.373 ^{NS}	17.512*
Cereal crops	3	2.671*	6.397*
Cutting management × Cereal crops	6	0.178*	1.733*
Error	24	0.017	0.018
Total	35	0.293	1.858

* indicates significant at 5% level of probability
NS = Non-significant

Appendix XII. Analysis of variance (mean square) of yield contributing parameters of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of			
		Number of grains spike^{-1}	Number of unfilled grains spike^{-1}	Weight of grains spike^{-1}	Spike length
Cutting management	2	18.016 ^{NS}	0.968 ^{NS}	0.026 ^{NS}	0.541 ^{NS}
Cereal crops	3	362.876 ^{NS}	0.641 ^{NS}	5.911*	295.077*
Cutting management × Cereal crops	6	31.988*	0.203 ^{NS}	0.298*	1.510*
Error	24	66.971	0.697	0.815	2.117
Total	35	83.540	0.623	1.118	27.033

* indicates significant at 5% level of probability
NS = Non-significant

Appendix XIII. Analysis of variance (mean square) of yield and harvest index of Cereal crops

Source of variation	Degrees of freedom	Mean Square value of			
		Grain yield	Straw yield	Biological yield	Harvest index
Cutting management	2	3.034 ^{NS}	0.539 ^{NS}	6.129 ^{NS}	70.042 ^{NS}
Cereal crops	3	4.909*	143.727*	184.674*	1210.463*
Cutting management × Cereal crops	6	1.257*	2.120*	6.435*	6.486*
Error	24	0.721	1.838	4.428	8.731
Total	35	1.304	13.974	20.319	114.855

* indicates significant at 5% level of probability
NS = Non-significant