EFFECT OF IRRIGATION MANAGEMENT ON GROWTH AND YIELD OF FODDER GRASSES

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CERTIFICATE

This is to certify that the thesis entitled ***"Effect of irrigation management on growth and yield of fodder grasses"*** *submitted to the* ***Department of Animal Production & Management****, Faculty of* ***Animal Science & Veterinary Medicine****, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTERS OF SCIENCE (M.S.)*** *in* ***Animal Science****, embodies the result of a piece of bona fide research work carried out by* ***MD. Al-AMIN****, Registration No.* ***19-10078, January- June /2021*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated : June, 2021
Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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The Author

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ABSTRACT

The experiment was carried out to study the effect of irrigation management on growth and yield of fodder grasses conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2020 to January 2021. Four grass varieties *viz.* V_1 (Napier grass), V_2 (Para grass), V_3 (Pakchong grass) and V_4 (German grass) with four levels of irrigation including control *viz.* I_0 (control; no irrigation), I_1 (Irrigation at 20 days of plantation), I_2 (Irrigation at 20 and 40 days of plantation) and I_3 (Irrigation at 20, 40 and 60 days of plantation) were considered for the present study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Regarding varietal performance, V_3 (Pakchong grass) performed best in terms of growth, yield and yield contributing parameters followed by V_1 (Napier grass) but the variety V_2 (Para grass) gave the highest protein content compared to other varieties. In terms of irrigation effect considering growth, yield and yield contributing parameters and quality parameters I_3 (Irrigation at 20, 40 and 60 days of plantation) showed the best performance in comparison to other irrigation treatments including control. In case of the treatment combination of variety and irrigation, the highest plant height (90.47 cm), number of leaves plant^{-1} (45.10), number of branches plant^{-1} (18.73), internode length (11.97 cm), number of internodes tiller^{-1} (10.77), fresh weight plant^{-1} (436.10 g), dry weight plant^{-1} (54.73 g), fresh weight plot^{-1} (5.23 kg) and fresh yield ha^{-1} (9.69 t) were achieved from V_3I_3 whereas control irrigation I_0 (no irrigation) gave the lowest results on respected parameters. Regarding quality parameter, the highest protein content (12.93%) was recorded from V_2I_3 whereas V_1I_0 gave the lowest protein content (7.45%). So, it can be concluded that the treatment combination of V_3I_3 (Pakchong grass with 3 Irrigations at 20, 40 and 60 days of plantation) can be considered as the best compared to other treatment combinations and can be suggested at field level application.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAP	=	Days After Plantation
DM	=	Dry Matter
DCP	=	Di-Calcium Phosphate
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
ILRI	=	International Livestock Research Institute
IVOMD	=	*In vitro* Organic Matter Digestibility
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ME	=	Metabolic Energy
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
UNDP	=	United Nations Development Programme
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

In Bangladesh, fodder production is very important because the fodder is a basic source of energy utilized for feeding the livestock. High performance of farm animals, especially dairy cows, depends on the availability of adequate amounts of quality fodder and in developing countries, inadequacy of quality fodder is the critical limitation to profitable animal production (Sarwar *et al*. 2002). Among the many options for overcoming the shortage of fodder, the introduction of high-yielding crop varieties ranks highly (Bilal *et al*. 2001). However, in many developing countries, because of the ever-growing need for food for humans, only limited cultivated land can be allocated to produce fodder for livestock.

A diet of ruminant consists of roughage and concentrate. Crop residues, green grasses, tree foliage and leaves are major sources of roughage for the ruminant of Bangladesh**.** Feeding to satisfy appetite, one of the pre-conditions for supplying nutrition to ruminants, requires availability of bulk that comes from roughages. Roughage quality is one of the basic requirements for optimizing intake and digestion kinetics in the rumen to make production efficient and economic. Farmer's problem of both quantity and quality of roughage that fluctuates on cropping seasons and regions hinders dairy and fattening cattle production in the country. From a recent study on the availability of feeds and fodder, it is evident that the availability of nutrients are 73.11% DM, 18.49% DCP and 25.24% ME with the deficits of 26.89% DM, 81.51% DCP and 74.76% ME, respectively (Akbar and Khaleduzzaman, 2009). Fodder nutrients such as crude protein, cellulose, and crush ash are indicators to assess fodder quality and verify the effectiveness of irrigation in artificial grassland (Zheng *et al*., 2016). Changes of nutrient contents were consistent with vegetation stages and management measures such as irrigation (Antoniewicz *et al*., 1995). Fodders with high crude protein usually have high nutrient levels and have been verified to increase maximal milk and protein production of dairy cows when the content of crude protein is no more than 16.5% (Colmenero and Broderick, 2006).

Livestock plays a vital role in agriculture of the country (Tabassum *et al*., 2008). Dairying in Bangladesh is a preferred option to generate income, accumulate assets and alleviate poverty (Khan *et al*., 2009; Tabassum *et al*., 2008). Livestock provides meat and milk, thus plays an important role in human health and nutrition (Chawdhury *et al*., 2016). The demand for meat and milk in the country are increasing by time (Huque and Sarker, 2014). Scarcity of green fodder is one of the major constrains of dairy farming in Bangladesh (Khan *et al*., 2009; Roy *et al*., 2012). There is no well-defined pasture area in this country (Tabassum *et al*., 2008). Ruminants of the country mostly depend on crop residues, agro-industrial by-products, naturally grown leaves from trees and native grasses from roadside verges, aquatic plants and fallows (Roy *et al*., 2012; Chawdhury *et al*., 2016). These areas are used as pasture for all kinds of ruminants are not maintained for improving the yield for animal feed. Productivity of these pastures is low (Tabassum *et al*., 2008) and influenced by season and climate.

In Bangladesh, there is a requirement of 70 million metric tons of green grass for cattle feed in a year but production is only 24 million metric tons. This 65% deficit is hampering the livestock production to a great extent (Roy *et al*., 2012). Poor nutrition results in low production and reproductive performance, slow growth rate, loss of body condition and increased susceptibility to diseases and parasites (Khan *et al*., 2009; Islam *et al*., 2016). Due to increased pressure of human population, most of the pasture lands are being now converting to crop cultivation (Miah and Noman, 2003). Fodder cultivation is mostly limited to the large farms. Poor marginalized farmers are still not well acquainted with fodder cultivation. This is why, feed available for ruminant livestock is not sufficient in the country.

Various reasons cause to depress the fodder production which are level of high yielding and disease resistant varieties, weeds infestation, the substandard method of cultivation etc. (Ehsas *et al*., 2018). The most problem which is facing our farmer is the level of high yielding and resistant varieties. For improving a good fodder-production system; choosing the best varieties of fodder crops is an important issue. It is very important to find high quality and certified varieties. Cultivation of highly productive and adapted varieties not only necessary for the good production of fodder crops but also helps to have healthy and forceful stands (Shroyer *et al*., 1998, Ehsas *et al*., 2018).

Another problem which is facing our farmer is lack of irrigation management (Ehsas *et al*., 2018). Water scarcity is an important limitation for fodder growth in grasslands in arid regions (Ren *et al*., 2017). Most key yield-limiting factor in Bangladesh is the management of irrigation. Using more amount of water, water stress, and absence of good drainage are main problems for fodder crop production (Ehsas *et al*., 2018). Water stress often enhances the quality of fodder, since the ratio of leaf-stem is boosting due to lack of the stem component's growth (Marble, 1990). Studies have shown that irrigated grasslands may have higher and more stable rates of yield (Dantas *et al*., 2016).

The effective irrigation water management practices and maximization water productivity is the desired target for higher fodder production. Farmers have tendency to apply huge quantity of water with large irrigation interval creating water logging condition (Marathe *et al*., 2001) especially in surface irrigation method. Whenever, irrigation water is on surface layers that lead to imbalance in nutrient uptake thereby adversely affecting growth of the plants (Marathe *et al*., 2016). One of the most important methods of water conservation are saving irrigation water by increasing irrigation intervals or decreasing irrigation depths. In this respect, Anton *et al*. (1995) stated that, the ecological importance of water is the result of its physiological importance. Every plant process is affected directly or indirectly by water supply. Seyed *et al*. (2011) noticed that the increases on irrigation intervals decrease fodder yield in sorghum. Alian and Mokhtar (2014) and Abbas *et al*., (2017) reported that the number of applied irrigations, seasonal water consumptive use and fresh yield of forging crop were increased with decreasing irrigation interval days. However, yields are linearly associated with the availability of water and are dramatically decreased by water stress. The loss in yield linked with the stress of water is so great. Increased irrigation interval cause to boost deeper roots that improve absorption huge quantity of nutrients per plant and assembling of these nutrients in the crop (stems and leaves) (Adam, 2015).

Bangladesh is primarily an agrarian economy. Livestock 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. But in Bangladesh only 3% land belongs under shrub lands, savanna, and grasslands. Among them the position of grass land alone will be less than 1% of total land area (Tabassum *et al*., 2008). This amount of land is too low to supply the feed requirements for our livestock. Fodder and feed scarcities are major limiting factors in ruminant livestock production in Bangladesh (Haque *et al*., 2006). Imports to fill the gaps are rarely feasible or economic, and seasonal feed shortages mean high fodder prices and poor livestock production performance.

In Bangladesh, it is urgently needed to increase production of fodder crops to meet up shortage. In this sector, there are huge scopes to improve fodder production which might be contributed to produce quality livestock products; it might be considered as great prospects for economic improvement of farmers by generating income and employment opportunity (Tabassum *et al*., 2008; Haque *et al*., 2006). Commercially fodder production also has great prospects to generate high income due to its demands and usefulness to produce quality livestock products (Tabassum *et al*., 2008). The situation is worse in areas often affected by drought and during March to May when the quantity of fodder is insufficient and its protein and energy values are low. Seasonal effect of fodder production is of great extent. All year round, fodder production can be produced but only small amounts of quality fodder and feed are available because of small land holdings and multiple attractive crop options during the cool dry (Rabi) season from November to March (Ahmed and Meisner 2002; Saadullah, 2002).

However, achieving high output yields with suitable variety of fodder crop also with optimum irrigation regarding existing environment in efficient and sustainable manners are the key challenges. Considering the above facts, the present study was conducted with the following objectives:

1. To find out the varietal performance of different fodder grasses on growth and yield
2. To find out the optimum irrigation frequencies for growth and yield of different fodder grasses
3. To find out the best fodder grass in combination with suitable irrigation frequencies regarding better performance on growth and yield

CHAPTER II

REVIEW OF LITERATURE

Livestock plays a vital role in agriculture of the country (Tabassum *et al*., 2008). Fodder shortage does exist since long ago and is increased with recent rapid population growth in Bangladesh. It has remained one of the major limiting factors of livestock production in the country. There are some published reports on fodder production regarding varietal performance and water management and related activities. A short description on the available literature relevant to the present investigation is presented here. Some of the important and informative works conducted home and abroad in this aspect, have been reviewed below:

2.1 Role of variety for fodder production

Varietal differences could be a major source of variation in biomass yield and fodder quality (Minson 1990). Improved varieties from the International Livestock Research Institute (ILRI) have been compared with the local variety for yield and nutritive value (Dzimale, 2000; Ansah *et al*., 2010), where the local variety compared favorably with the improved varieties. Based on the biomass yields and nutritive value obtained in these experiments in the humid zone, 3 improved varieties from ILRI and the local variety were selected for evaluation in the northern savanna zone in terms of forage yield and quality. The northern savanna zone has the highest population of ruminant livestock, and is characterized by a unimodal rainfall pattern with about 7 months of dry season, which significantly affects both biomass yield and fodder quality for livestock production (Ansah *et al*., 2010).

Sarker *et al*. (2021) conducted a study to evaluate the performance of napier cultivars in terms of forage yield, plant morphology and nutrient contents under two different agro-ecology and geo-topographic conditions. Three napier cultivars being conserved by Bangladesh Livestock Research Institute (BLRI), namely-BLRI-Napier 1, (BN-1), BLRI-Napier 3 (BN-3) and Merkeron (BN-5) were selected to cultivate in severe drought prone areas (called Barind) and non-drought area at Savar (Modhupur terrace). Stem cuttings were planted in rows apart from 70 cm and 35 cm spacing between plants. Data of 6 consecutive harvests from a period of approximately one year were collected and analyzed statistically. The results showed that cultivar and location had a significant effect on biomass yield, plant height and leaf-stem ratio (LSR). BN-3 yielded the highest biomass (33.32 t/ha/harvest) at non1drought location (42.98 t/ha/harvest). The highest plant height was obtained in BN-1 (174.6 cm). Number of tillers per hill ranged from 25.4 to 26.3 among cultivars. The proximate analysis showed that CP, ADF and NDF in whole plant were varied significantly, being the highest contents in BN-1 (10.69%, 46.20% and 54.58%, respectively). Finally, the experiment reveals the superiority in biomass yield and nutritional quality (in terms of CP content) with the ranking orders of BN-3 > BN-1 > BN-5 and BN-1 > BN-3 > BN-5.

Getiso and Mijena (2021) conducted an experiment with six napier grass accessions (*Penisetum purpuruem*) that have been tested and identified for their better agronomic and yield performance under two sets (irrigation and rainfed) conditions. The experiment was conducted in randomized complete block design with three replications. Napier accessions 14983, 15743 and 16788 responds better mean fresh and dry biomass yield. Hence, among tested genotypes 14983, 15743 and 16788 napier grass accessions will be encouraged in the study area and similar environment.

Bacchi *et al*. (2021) conducted a study and evaluated the crop yield and quality of seven annual forages (four grasses and three legumes) in sole crop and in mixtures (ratio 50:50) for oat (*Avena sativa* L.), Italian ryegrass (*Lolium multiflorum* Lam.), *triticale* (× *Triticosecale* Wittmack), barley (*Hordeum vulgare* L.), pea (*Pisum sativum* L.), berseem (*Trifolium alexandrinum* L.) and common vetch (*Vicia sativa* L.) in a two-year field experiment adopting two harvesting times, green fodder and silage. The main bio-agronomic traits, dry matter forage yield (DMY) and quantity of crude protein (CP) were determined in both sole crop and intercrop. The land equivalent ratio (LER) was used for evaluating biological efficiency and competitive ability of the intercrops. Results showed that the internode length, number of internodes tiller^{-1}, total calculated LER for fodder and protein yields was always greater than one and corresponded to crop yield advantages of 16.0% and 11.5%, respectively. Data also highlighted the low competitive ability of the ryegrass in intercrop, which achieved the lowest yield among all the mixtures. Conversely, the same grass showed the best green fodder quality, due to the high incidence of the legume, equal (on average) to 46%. Triticale and barley, harvested for silage (hard dough stage), provided the best quantitative and qualitative results both in sole crop and intercropped with common vetch and pea, determined mainly by the cereal grain.

Hidosa and Kibiret (2020) reported that *Pennisetum perpureum* grass species could play an important role in providing a significant amount of high quality dry matter yield to the livestock and initiated this study to evaluate dry matter yield and chemical composition of 5 *Pennisetum perpureum* grass varieties in irrigated lowland. The five *Pennisetum perpureum* grass varieties were evaluated in randomized complete block design with 3 replications per variety. The data on dry matter yield, plant height, tillers per plant, leaf to stem ratio and nutritional qualities were analyzed using the general linear model procedures. The higher dry matter yield (51.56 t ha^{-1}) was recorded for ILRI16840 variety and whereas, the lowest dry matter yield (34.06 t ha^{-1}) was for ILRI168902 variety. Moreover, significantly higher crude protein (161.70 g kg^{-1}, DM) recorded for ILRI16815 and whereas, significantly lowest crude protein (126 g kg^{-1}, DM) for ILRI168902 variety. On basis of results it can be calculated that the variety ILRI16840 followed by variety ILRI16815 for higher dry matter yield and whereas, for crude protein content the variety ILRI16815 followed by variety ILRI16813 was considered as the best.

Shedrack *et al*. (2019) conducted a study and reported that *Pennisetum purpureum* (napier) is known to be a high-yielding and nutritious grass species for ruminant livestock. In this study the fodder yield and nutritive value of 3 varieties (ILRI accessions 16837, 16798, 16840) of *Pennisetum purpureum* (napier) grass were compared with those of the local variety in the savanna region of Ghana. A randomized complete block design was used to assess yield performance over a 90-day period. After 90 days, the grasses were harvested to a stubble height of 15 cm and samples of the harvested fodder were separated into leaves and stems, while some remained whole. These samples were analyzed for nutrient composition and in vitro organic matter digestibility (IVOMD). There was no significant effect of variety on biomass yield (1,354–3,339 kg DM/ha), tiller number (9.5–16.1/plant), plant height (1.1– 1.4 m) or leaf: stem ratio (0.9–1.2). Plant height was positively correlated with biomass yield. The stem fraction for all varieties had consistently (P >0.05) lower crude protein (CP) concentrations than the leaf fraction with the lowest levels recorded in the local variety. The study revealed a superior yield performance for the local variety but not significantly, with the improved varieties having a higher CP. From these results, there is no justification for introducing the improved cultivars studied in place of the local variety.

Jha *et al*. (2016) conducted a research to evaluate the effect of irrigation method on the productivity of nutritious fodder species during off-monsoon dry periods. Commonly used local agronomical practices were followed in all respects except irrigation method. Species effects were significant, with teosinte (*Euchlaena mexicana*) having higher yield than cowpea (*Vigna unguiculata*). Higher productivity of these nutritional fodders resulted in higher milk productivity for livestock smallholders.

2.2 Role of irrigation for fodder production

Sarker *et al.* (2021) conducted a study to evaluate the performance of napier cultivars in terms of forage yield, plant morphology and nutrient contents under two different agro-ecology and geo-topographic conditions. Three napier cultivars being conserved by Bangladesh Livestock Research Institute (BLRI), namely-BLRI-Napier 1, (BN-1), BLRI-Napier 3 (BN-3) and Merkeron (BN-5) were selected to cultivate in severe drought prone areas (called Barind) and non-drought area at Savar (Modhupur terrace). Stem cuttings were planted in rows apart from 70 cm and 35cm spacing between plants. Data of 6 consecutive harvests from a period of approximately one year were collected and analyzed statistically. The results showed that cultivar and location had a significant effect on biomass yield, plant height and leaf-stem ratio (LSR), while number of tillers were significantly varied with locations. The highest plant height was obtained in BN-1 (171.2 cm) at drought location. The highest tillers were found at non-drought location (28.1 no). The highest CP content in whole plant was obtained at non-drought location (11.89%), while the lowest ash (10.57%) and NDF (52.71%) contents were obtained at the same location. The highest CP con1tents in leaf were found at non-drought (15.03%) and the lowest ash (9.86%) at the same location. The highest CP contents (5.90%) in stem were found at non-drought location, while the lowest ash (11.28%) and NDF (54.59%) contents were obtained at the same location.

Getiso and Mijena (2021) conducted an experiment with six napier grass accessions (*Penisetum purpuruem*) under two sets of irrigation and rainfed conditions in randomized complete block design with three replications. Under supplementary irrigation there was no significant difference of mean yield and yield components observed among accessions both under fertilizer application and without fertilizer application with fresh biomass yield (t/ha) ranged from 43.73 to 70.24 and that of dry biomass yield (t/ha) ranged 11.54 to 20.32. Under rainfed condition the combined mean analysis for tiller number per plant, plant height, node number per plant and internodes length per plant did show significant difference. Fresh biomass yield (59.11 t/ha) and dry matter yield (16.17 t/ha) for fertilizer application is significantly higher than fresh biomass and dry matter yield of 40.51 t/ha and 10.51 t/ha, respectively, for non-fertilizer applied napier accessions under rainfed condition.

Canto *et al*. (2020) conducted a field experiment to evaluated the effects of nitrogen (N) fertilizer rate and irrigation on seed yield and its components for signal grass (*Urochloa decumbens)*. Two water regimes (irrigated and non-irrigated) and four nitrogen (N) fertilizer rates (0, 25, 50 and 75 kg ha^{-1}) were applied to perennial signal grass crops in a split-plot randomized complete block design with three replications. In two consecutive harvests, favourable rainfall resulted in irrigation having limited influence on most measurements, and the combined application of irrigation and N fertilizer did not improve seed yield. Compared with the nil N, the highest N application rate significantly increased seed yield for the first crop (266 vs 498 kg ha^{-1}) and the second crop (104 vs 286 kg ha^{-1}). Nitrogen fertilisation significantly increased number of seed per area, reproductive tiller density and plant biomass at harvest for the first and second crops. Harvest index, 1000-seed weight, reproductive tiller weight, number of spikelets per panicle and number of seeds per panicle were unaffected by N rate but affected by irrigation.

Suganthi *et al*. (2019) conducted a field experiment to study the irrigation frequency for CN hybrid grass and asses the growth and yield of Cumbu Napier Hybrid grass variety CO-4. The experiment was laid out with Randomised Block Design. The treatment consist of different irrigation frequency such as daily irrigation (T_1) alternate day irrigation (T_2) once in two days (T_3) , once in four days (T_4), once in six days (T_5) once in eight days (T_6) once in ten days (T_7), once in twelve days (T_8) and once in fourteen days (T_9) were compared. Among the different irrigation frequency, irrigation at once in four days and irrigation at once in six days significantly increased the growth and yield characters, reduced the cutting frequency, increased number of cuttings and yield of Cumbu Napier Hybrid Grass. These two treatments were comparable with each other. The maximum plant height, number of tillers hill^{-1}, fodder yield were higher in these treatments. The fodder yield was lower in fourteen days of irrigation and twelve days of irrigation frequency.

Islam *et al*. (2017) conducted a study to find out a suitable fodder for floating bed fodder cultivation. Later, German grass was cultivated on five floating beds at Hemupara of Jaintapur, Sylhet and also produced at land of SAU campus. German grass samples from both floating beds and land, as well as local Bermuda grass from Hemupara were evaluated for assessment of biomass production, proximate and fiber composition. There was no significant difference in length and production of German grass cultivated on floating bed and land cultivation. German grass production cost on floating bed was 2.3 Tk/kg. German grass from floating bed contained more ether extract, ash, neutral detergent fiber and cellulose than that from land cultivation. DM, ash, CP, EE, CF and NFE of German grass on floating beds at Hemupara were 199.7 g/kg, 20.1 g/kg, 57.2 g/kg, 37.2 g/kg, 411.8 g/kg and 273.9 g/kg respectively. The fiber components of German grass on floating beds were NDF (696.4 g/kg), ADF (452.2 g/kg), ADL (100.1 g/kg), cellulose (244.1 g/kg) and hemicellulose (352.1 g/kg). German grass can be considered as a suitable fodder for floating bed fodder cultivation when there is long term water logging as an alternative fodder production practice in Bangladesh.

Tian *et al*. (2017) carried out comparison experiments to assess the impacts of irrigation schemes on forage yield, water use efficiency, and nutrients in the single and mixed sowing ways of *Medicago sativa* L. and *Agropyron cristatum* in different stages in artificial grassland. Results indicated that deficit irrigation can increase forage yields of *M. sativa* and *A. cristatum* in most growth stages and sowing treatments. Heavy deficit irrigation or even no irrigation had the greatest potential to increase forage yields of both species in the squaring stage and instantaneous water-use efficiency (WUEI) in all growth stages. They can also significantly increase the nutritional level of *M. sativa* using a mixed sowing method. In June and September, only irrigating to near field capacity (T_1) can increase the long-term water-use efficiency (WUEL) of both species. The study suggests irrigating with water to near field capacity in June, and applying deficit irrigation in July and August. Deficit irrigation is an effective water management technique to both save water and increase forage quality in arid areas.

Koech *et al*. (2016) carried out a study for making sustainable management of irrigation water and also increased pasture productivity at the current intensification of the production systems. Above ground biomass of six rangeland grasses (*Chloris roxburghiana*, *Eragrostis superba*, *Enteropogon macrostachyus*, *Cenchrus ciliaris*, *Chloris gayana*, and *Sorghum sudanense*) in pure and mixed stands at 80, 50 and 30% soil moisture field capacity (FC), and control under rainfed as main plots. The main plots were divided into 30 subplots and randomly allocated ten grass species in three replicates. The moisture content was monitored by gypsum blocks which aided in irrigation times and levels. Seeds were sown by broadcast method in tractor ploughed and harrowed to fine tilt land. Biomass and growth morphometric characteristics were measured at phenological growth stages of 10, 12 and 14 weeks, representing vegetative stage, flowering and seed setting and mature with ripened seed stages for the studied range grasses. All the irrigated treatment yielded significantly higher above ground dry matter than the rainfed. *S. sudanense* had the highest yields at 80% FC (13.7 t ha^{-1}), though not significantly different from the 50 and 30% FC (11.6 and 7.7 t ha^{-1}), respectively. *C. gayana* and *C. roxbhurghiana* yields were not significantly affected by changes in soil moisture content with yields ranging between 10.1 and 10.8 t ha^{-1}. *C. ciliaris* performed better at 50% FC (9.1 t ha^{-1}). Differences in tiller numbers across the watering treatments and grass species were not significant, but very low under rainfed conditions. The tiller heights in all the species were lower under rainfed than irrigated treatments. *S. sudanense* had the highest tiller height and biomass followed by *C. gayana* and *E. Macrostachyus*, respectively. Here we demonstrate that the production of range pastures under irrigation in the arid environments should consider individual species responses to different soil moisture content for better yields and water conservation. The results show the species of importance for consideration under irrigation systems are *S. sudanense* and *C. gayana*.

Alghobar and Suresha (2016) conducted an experiment to study the effect of waste water irrigation on plant growth and yield of tomato, napier grass and sugarcane crops was compared with that of ground water irrigation. Treatments included untreated wastewater (UWW) treated wastewater (TWW) and ground water (GW) as control.

The results obtained, plant height, dry biomass g/plant, number of branches/plant of tomato (78.46 cm, 45.88, 15.49 and 11.41) and (75.13 cm, 41.48, 14.42 and 10.28) were significantly higher in the UWW and TWW compared to GW. The UWW and TWW irrigated napier grass gave the highest growth and yield, compared to that of GW irrigation. Plant height, number of leaves/plant, leaf length, leaf width and number of tiller were 188.46 cm, 83.62, 93.62 cm, 2.52 cm and 13.2 in UWW and 182.68 cm, 69.75, 88.67cm, 2.29 cm and 10.39 in TWW and these are significantly higher as compared to that of GW irrigation. Wastewater irrigation of sugarcane increased cane length, number of nodes/cane, number of leaves, cane diameter and cane weight significantly as compared to control GW are 191.86 cm, 22.48, 39.3 and 2.30 cm in UWW and 149.4 cm, 20.54, 27.53 and 2.22 cm in TWW and compared to that of GW irrigation.

Jha *et al*. (2016) reported that improved irrigation use efficiency is an important tool for intensifying and diversifying agriculture, resulting in higher economic yield from irrigated farmlands with a minimum input of water and conducted a research to evaluate the effect of irrigation method (furrow vs. drip) on the productivity of nutritious fodder species during off-monsoon dry periods. A split-block factorial design was used. The factors considered were treatment location, fodder crop, and irrigation method. Commonly used local agronomical practices were followed in all respects except irrigation method. Species effects were significant, with teosinte (*Euchlaena mexicana*) having higher yield than cowpea (*Vigna unguiculata*). Irrigation method impacted green biomass yield (higher with furrow irrigation) but both methods yielded similar dry biomass, while water use was 73% less under drip irrigation. The present findings indicated that the controlled application of water through drip irrigation is able to produce acceptable yields of nutritionally dense fodder species during dry seasons, leading to more effective utilization and resource conservation of available land, fertilizer and water.

Norsuwan *et al*. (2016) conducted a field experiment to investigate the effects of various irrigation treatments, namely rainfed conditions, 0.5 × ET0 (Reference Evapotranspiration), 1.0 × ET_0 , and nitrogen application rates of 0, 120, 240 and 300 kg N ha^{-1}, on biomass production of napier grass. After the 1st harvest, ET_0 was calculated and applied to the field by drip irrigation system every five days. Napier grass was harvested three times, firstly two months after planting, then at one and two months after the first harvest. The experimental results showed that applying $0.5 \times ET_0$ could increase internode length and number of internodes tiller^{-1} and also total dry matter yield of napier grass varied from 4344 kg ha^{-1} under rainfed conditions to 6260 kg ha^{-1}. However, the interaction of 1.0 × ET0 and 300 kg N ha^{-1} application could potentially reach above ground dry matter yield up to 12,000 kg DM ha^{-1}.

Jafarian *et al*. (2015) conducted an experiment to evaluate the response of alfalfa to limited irrigation and surfactant application. The experimental treatments were arranged as split plots based on a complete randomized block design with three replications. The limited irrigation treatments comprised of replenishment of 100%, 75% and 50% of weekly evaporation and plant water requirements assigned to the main plots. Water treatments of control (water alone) and water + surfactant, assigned to the subplots. The quantitative and physiological characteristics of alfalfa forage were recorded at 10% flowering stage. The seed yield of alfalfa was measured after the plants reached full physiological maturity stage. The result of the experiment showed that as the severity of limited irrigation increased, plant height, tiller number per plant, RWC, total forge yield and seed yield followed a decreasing trend. Across all the limited irrigation systems, surfactant application increased plant height, RWC, seed yield and total forge yield. As the severity of limited irrigation increased, water use efficiency (WUE) in forage yield followed a significant increasing trend. The highest forage (7500 kg/ha) and seed yield (820 kg/ha) under limited irrigation treatments were achieved at 75% weekly evaporation and plant water requirements + surfactant, while the highest irrigation water use efficiency for forage (1.5 kg/m^3) and seed (0.16 kg/m^3) production was observed in limited irrigation treatment of 50% weekly evaporation and plant water requirements + surfactant.

Water scarcity is an important limitation for forage growth in grasslands in arid regions (Ates *et al*., 2012 and Ren *et al*., 2017). Studies have shown that irrigated grasslands may have higher and more stable rates of yield (Dantas *et al*., 2016 and Sanches *et al*., 2017). However, achieving high output yields with less irrigation in an efficient and sustainable manner is one of the key challenges in artificial grasslands in arid areas. Deficit irrigation is irrigating with limited water to obtain maximum water use efficiency and stable yields instead of obtaining maximum yields. One effective way to solve water scarcity problems is by optimizing plant water usage through enhancing yield, water use efficiency, and nutritional levels by applying deficit irrigation (English *et al*., 1990).

Sikuku *et al*. (2010) noticed that water deficit has no significant effect on chlorophyll fluorescence parameters. The total chlorophyll and protein content decline with the rising water deficit under moisture deficit conditions.

Amal *et al*. (2010) observed that Pioneer F-840 cultivar mostly surpassed Giza113 cultivar in total fresh weight, dry weight, leaf area, specific leaf area, NAR, yield and its components. Neglecting one irrigation at different growth stages led to a significant reduction in plant height, TFW, TDW, LA, LAI, SLA, NAR and CGR. Similarly, Aishah *et al*. (2011) reported that the irrigation frequency was found to affect growth and yield of the forage sorghums. When irrigation was delayed in leaf water potential of -1.0 to - 2.0 MPa, the yield and yield components were found to decrease.

Cehchin (1998) found in sorghum cultivars C51 and C42 that water stress results in lower net photosynthetic rate, stomatal conductance and transpiration rate in both varieties. Water stress causes a slight decrease in the efficiency of excitation capture by open PS2 reaction centers. Similarly, Tsuji *et al*. (2003) noticed that water stress reduced shoots dry mass of Gadambalia, Arousel Rimal and Tabat by 43, 46 and 58%, successively. Shoot fresh weight also reduced by water stress in Gadambalia, Arousel Rimal and Tabat. Relevant decrease in the leaf area of three cultivars was 28, 54 and 63%. Reduction in net photosynthetic rate, stomatal conductance and transpiration rate due to water stress was lowest in Gadambalia and highest in Tabat.

Singh and Singh (1995) studied that increased frequency of irrigation generally results in higher profile water content, leaf water potential, leaf osmotic potential, leaf turgor potential, leaf area index, evapotranspiration, net photosynthesis and dry matter yield in all species.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2020 to January 2021 to study the effect of irrigation management on growth and yield of fodder grasses. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Planting materials

Four varieties of fodder grasses *viz.* Napier grass, Para grass, Pakchong grass and German grass were used as planting materials.

3.5 Treatments of the experiment

The experiment comprised of two factors.

Factor A: Variety - Four

1. V_1 = Napier grass
2. V_2 = Para grass
3. V_3 = Pakchong grass
4. V_4 = German grass

Factor B: Irrigation management – Four

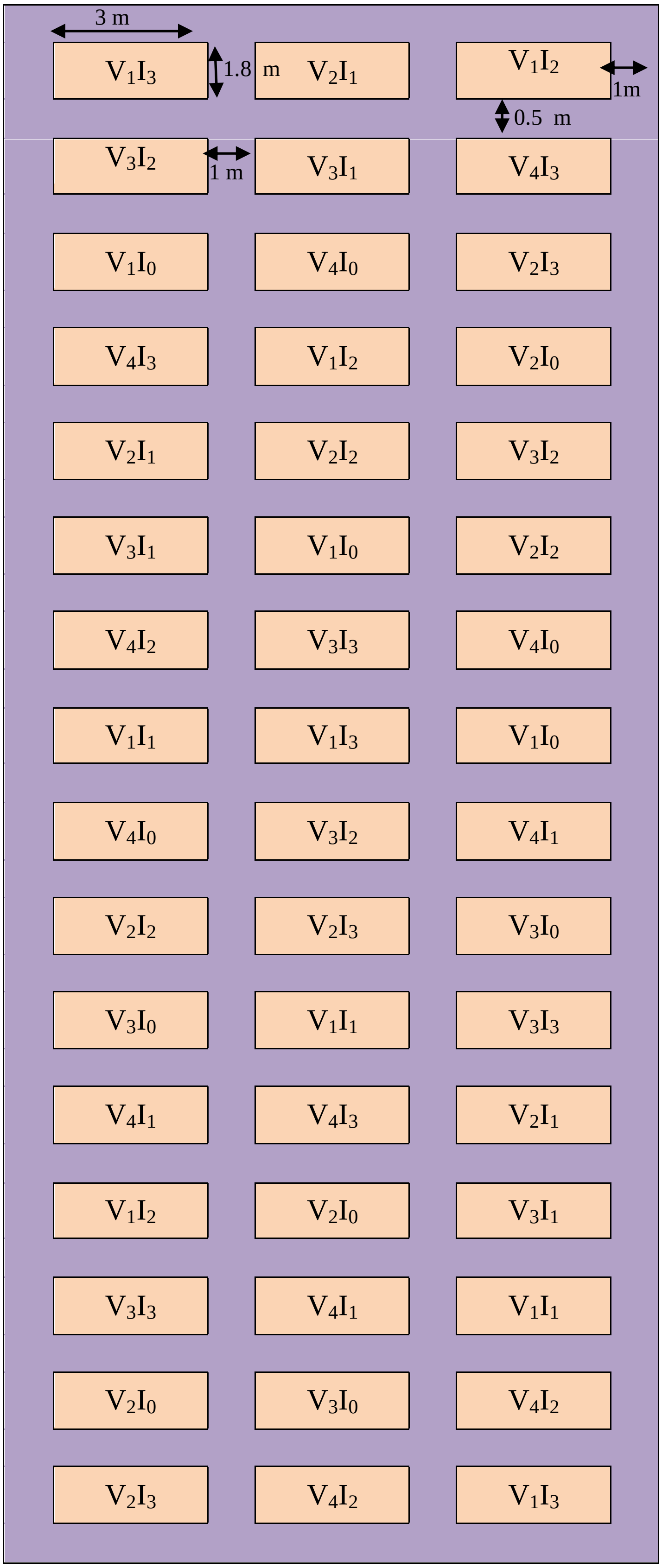
1. I_0 = Control (No irrigation)
2. I_1 = Irrigation at 20 days of plantation
3. I_2 = Irrigation at 20 and 40 days of plantation
4. I_3 = Irrigation at 20, 40 and 60 days of plantation

Treatment combinations – Sixteen treatment combinations

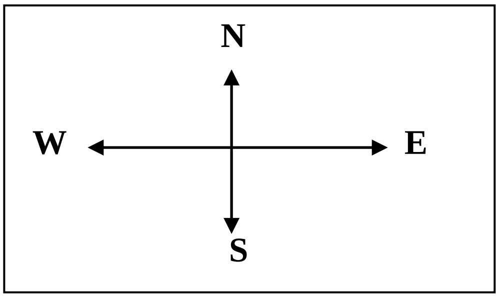
V_1I_0, V_1I_1, V_1I_2, V_1I_3, V_2I_0, V_2I_1, V_2I_2, V_2I_3, V_3I_0, V_3I_1, V_3I_2, V_3I_3, V_4I_0, V_4I_1, V_4I_2 and V_4I_3.

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of fodder grasses variety and irrigation. Four different fodder grass variety and four different irrigation treatments including control were considered. The 16 treatment combinations of the experiment were assigned. The area of the experimental plot was divided into three equal blocks. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. The size of each unit plot 3 m × 1.8 m. The distance between blocks and plots were 1 m and 0.5 m respectively. The layout of the experiment field is presented in Figure 1.



Legend



Treatments

Factor A: Variety - Four

1. V_1 = Napier grass
2. V_2 = Para grass
3. V_3 = Packchong grass
4. V_4 = German grass

Factor B: Irrigation– Four

1. I_0 = Control (No irrigation)
2. I_1 = Irrigation at 20 days of plantation
3. I_2 = Irrigation at 20 and 40 days of plantation
4. I_3 = Irrigation at 20, 40 and 60 days of plantation

Plot size = 3 m × 1.8 m

Plant spacing = 45 cm × 60 cm

Block to block distances = 1 m

Plot to plot distances = 0.5 m

Figure 1. Layout of the experimental plot

3.7 Variety used and collection

Under the present study, four fodder grasses variety (Napier grass, Para grass, Pakchong grass and German grass) were used and cuttings of these varieties were collected from Central Cattle Breeding & Dairy Farm, Savar, Dhaka.

3.8 Preparation of the main field

The plot selected for the experiment was opened in the 1st October, 2020 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for plantation. The land operation was completed on 4th October 2020. Irrigation channel was made within each plot to complete the irrigation treatments.

3.9 Fertilizers and manure application

Manures and fertilizers were applied as follows:

3.9.1 Napier and Pakchong grass

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	5 ton
N	Urea	150 kg
P	TSP	65 kg
K	MoP	65 kg

3.9.2 Para and German grass

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	5 ton
N	Urea	100 kg
P	TSP	65 kg
K	MoP	65 kg

The half of urea and total amount of cowdung, TSP and MOP was applied as basal dose at the time of land preparation. The rest amount of urea was applied in two installments at 30 and 50 days after plantation.

3.10 Grass plantation

Collected healthy and uniform cuttings were soaked with wet straw mulch for 7 days before plantation. Healthy and uniform cuttings of each variety were planted in the experimental field on 7^{th} October, 2020 maintaining a spacing of 45 cm × 60 cm. This operation was carried out during late hours in the evening. The cuttings were watered after plantation. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Intercultural Operation

After establishment of seedlings, various intercultural operations (gap filling and weeding, irrigation and plant protection) were accomplished for better growth and development of the fodder grasses.

3.11.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was crushed. A few gaps filling were done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.11.2 Irrigation

Irrigation was provided according to the treatments assigned.

3.11.3 Plant protection

The crop was protected from the attack of insect-pest by spraying Melathion 45 EC at the rate of 2 ml/L water. The insecticide application was done fortnightly as a matter of routine work.

3.12 Harvesting

The first harvest of the fodder grasses was done at 90 days of plantation (DAP). Harvesting was done using as sharp knife. During harvest, some necessary data were recorded. Harvesting was done manually. Proper care was taken during harvesting period to prevent damage.

3.13 Data collection and recording

Five plants were selected randomly from each unit plot for recording data on crop parameters and the yield. The following parameters were recorded during the study:

3.13.1 Growth parameters

1. Plant height (cm)
2. Number of leaves $plant^{-1}$
3. Number of branches $plant^{-1}$

3.13.2 Yield contributing parameters

1. Internode length (cm)
2. Number of internodes $tiller^{-1}$
3. Fresh weight $plant^{-1}$ (g)
4. Dry weight $plant^{-1}$ (g)

3.13.3 Yield parameters

1. Fresh weight $plot^{-1}$ (kg)
2. Fresh yield ha^{-1} (t)

3.13.4 Quality parameter

1. Crude protein content (%)

3.14 Procedure of recording data

3.14.1 Growth parameters

3.14.1.1 Plant height (cm)

Plant height was recorded at 30, 60 and 90 days after plantation (DAP). Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured in centimeter (cm) from the ground level to the tip of the leaves.

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

Number of leaves $plant^{-1}$ was counted at different days after plantation (DAP) of crop duration. Leaves number $plant^{-1}$ was recorded from together 5 plants by counting all leaves from each plot and mean was calculated. It was recorded at 30, 60 and 90 DAT and at harvest.

3.14.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} was recorded at 30, 60 and 90 days after plantation (DAP). Data were recorded as the average of 5 plants selected at random from the inner rows of each plot by counting all branches and mean was calculated.

3.14.2 Yield contributing parameters

3.14.2.1 Internode length (cm)

Internode length was measured by using a meter scale. The measurement was taken from base of the first internode to next and average was measured for each plant. From five random selected plants from inner rows of each plot was considered for measuring internode length. Data was recorded at 90 DAP. Mean was expressed in centimeter (cm).

3.14.2.2 Number of internodes tiller^{-1}

Number of internodes tiller^{-1} was recorded at 90 days after plantation (DAP). Data were recorded as the average of 5 plants selected at random from the inner rows of each plot by counting all tillers number with bearing all internodes number and mean was calculated.

3.14.2.3 Fresh weight plant^{-1} (g)

At the time of harvest, cuttings of grasses from five selected plants were taken and then mean was recorded and expressed in gram (g).

3.14.2.4 Dry weight plant^{-1} (g)

Cuttings of grasses from randomly selected 5 plants were taken. Samples were then dried in an oven at 70°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The average final weight of the sample was taken and expressed as dry matter content in gram (g).

3.14.3 Yield parameters

3.14.3.1 Fresh weight plot^{-1} (g)

Whole cuttings of grasses from each plot were collected and weight of cuttings was taken in kg.

3.14.3.2 Fresh yield ha^{-1} (t)

Whole cuttings of grasses from 1 m^2 inner rows of each plot was taken and weighed in gram and it was converted to t ha^{-1}.

3.14.4 Quality parameter

3.14.4.1 Crude protein content (%)

Dried fodder samples from each harvest were ground using a Thomas Scientific Wiley Mill (3379-K35 Variable Speed Digital ED-5 Wiley Mill, Swedesboro, NJ, USA). A maximum of 25 g of grounded materials were stored in 125 mL glass bottles for fodder nutritive analysis. Total Nitrogen (N) concentration was determined according to Noel and Hambleton (1976). Crude protein (CP) concentration was calculated by multiplying total Kjeldahl N by 6.25 (Jones, 1991).

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Plate 1. Layout preparation of experimental field

Plate 2. Germination procedure of fodder cuttings

Plate 3. Plantation of cuttings of fodder grasses

Plate 4. Sample irrigation in the experiment field

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out effect of irrigation management on growth and yield of fodder grasses. Analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of variety

Non-significant variation on plant height among different fodder grass varieties was recorded at 30 DAP, but at 60 and 90 DAP, significant variation was found on plant height of different fodder grasses (Figure 2 and Appendix IV). However, at 30 DAP, the highest plant height (43.53 cm) was observed from the variety V_3 (Pakchong grass) followed by V_1 (Napier grass) whereas the lowest plant height (41.03 cm) was found from the variety V_4 (German grass). At 60 DAP, the highest plant height (57.03 cm) was given by the variety V_3 (Pakchong grass) that was significantly different from others followed by V_1 (Napier grass) whereas the lowest plant height (51.84 cm) was found from the variety V_4 (German grass) that was statistically similar with V_2 (Para grass). At 90 DAP, the variety V_3 (Pakchong grass) gave the highest plant height (77.71 cm) which was significantly similar with V_1 (Napier grass) whereas the variety V_4 (German grass) showed the lowest plant height (71.61 cm) that was statistically similar with V_2 (Para grass). Similar result was also observed by Shedrack *et al*. (2019) and reported that plant height differed with varietal difference and observed that plant height was positively correlated with biomass yield. Sarker *et al*. (2021) also found similar result with the present study.

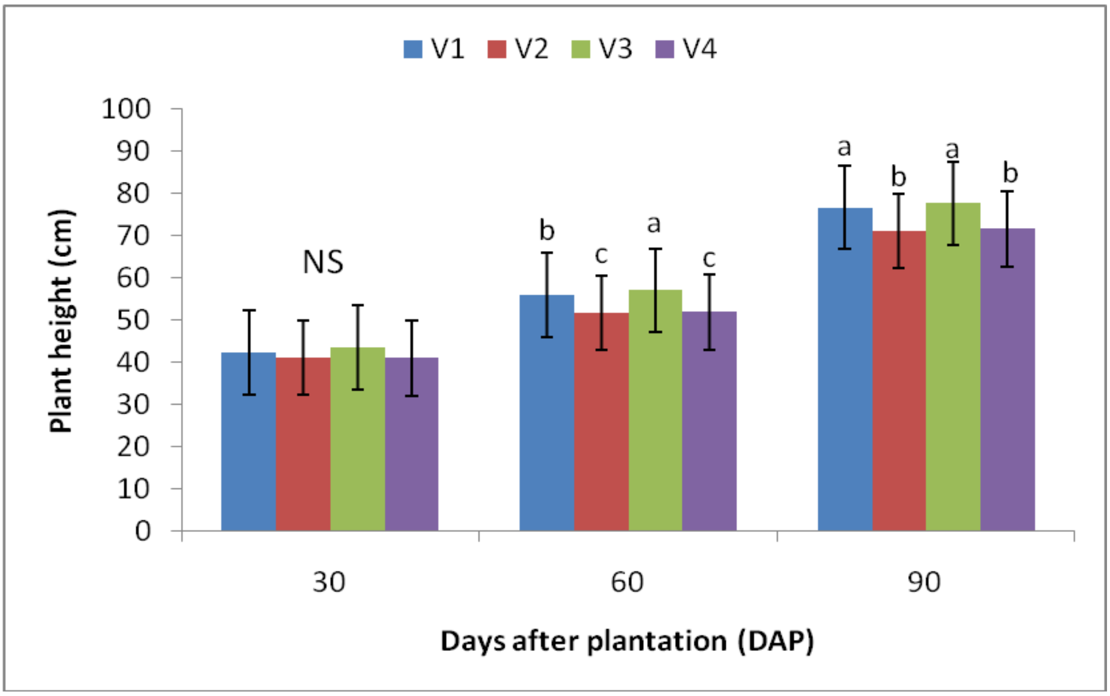


Figure 2. Plant height of fodder crops as influenced by different variety

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

4.1.1.2 Effect of irrigation

Different levels of irrigation including control showed significant variation on plant height of fodder grasses at different growth stages (Figure 3 and Appendix IV). Results exposed that at 30 DAP, the highest plant height (46.85 cm) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest plant height (36.29 cm) at 30 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different from other irrigation treatments. At 60 DAP, irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) represented the highest plant height (62.27 cm) that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest plant height (46.08 cm) at 60 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different from other irrigation treatments. Similarly, the highest plant height (83.69 cm) at 90 DAP was observed by the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) followed by I_2 (irrigation at 20 and 40 days of plantation) whereas the control irrigation I_0 (no irrigation) registered the lowest plant height (62.75 cm) at 90 DAP that was significantly different from other irrigation treatments. This result suggested that irrigation effect contributed to significant difference on plant growth. Koech *et al*. (2016) found similar result with the present study and reported that the plant height was lower under rainfed than irrigated treatments which was also in agreement with the findings of Suganthi *et al*. (2019).

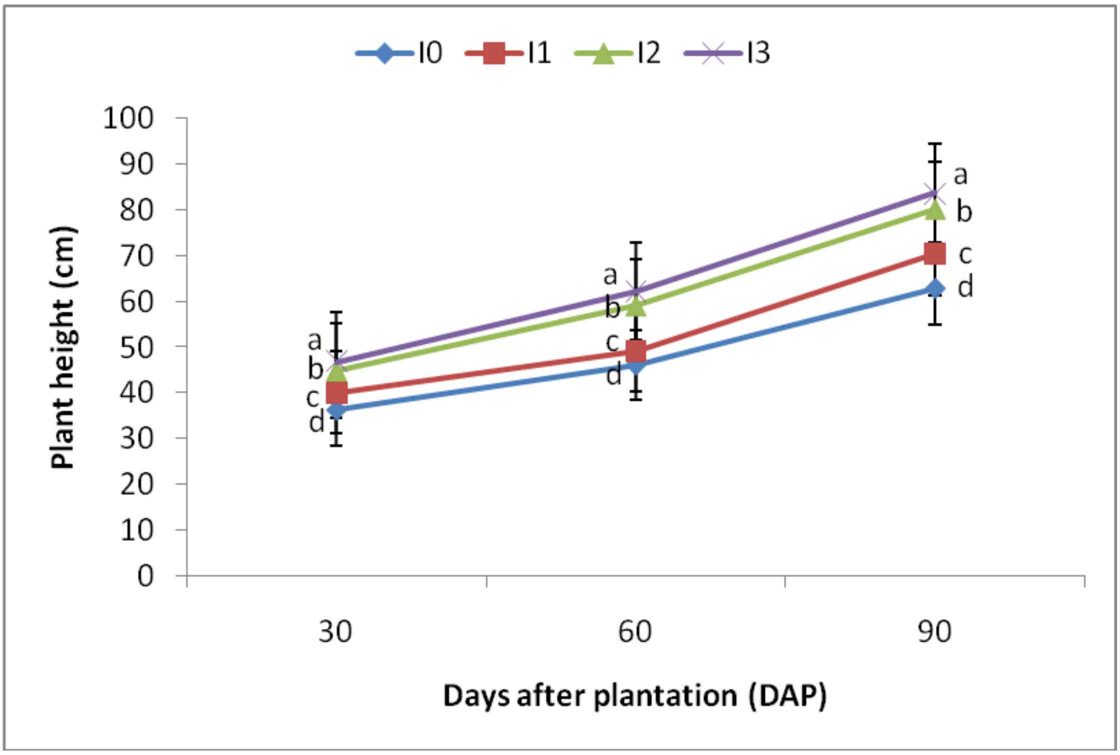


Figure 3. Plant height of fodder crops as influenced by different irrigation treatments

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.1.1.3 Combined effect of variety and irrigation

Combined effect of different variety and irrigation gave significant difference on plant height of fodder grasses among different combinations at different growth stages (Table 1 and Appendix IV). Results indicated that the treatment combination of V_3I_3 gave the highest plant height (49.17 cm) at 30 DAP that was significantly similar to V_1I_3 and V_3I_2 whereas the lowest plant height (34.73 cm) at 30 DAP was recorded from the treatment combination of V_1I_0 that was significantly similar to V_3I_0. Again, at 60 DAP, the treatment combination of V_3I_3 gave the highest plant height (66.23 cm) that was significantly similar to V_1I_3 and V_3I_2 whereas the lowest plant height at 60 DAP (45.00 cm) was found from the treatment combination of V_1I_0 that was significantly similar to V_2I_0 and V_3I_0. Likewise, at 90 DAP, V_3I_3 gave the highest plant height (90.47 cm) that was significantly similar to V_1I_3 whereas V_1I_0 registered the lowest plant height (61.17 cm) at 90 DAP that was similar to V_2I_0 and V_3I_0.

Table 1. Plant height of fodder crops as influenced by the combination of different variety and irrigations

Treatment	Plant height (cm)		
	30 DAP	60 DAP	90 DAP
V_1I_0	34.73^{h}	45.00^{h}	61.17^{j}
V_1I_1	40.07^{f}	50.40^{e}	70.80^{g}
V_1I_2	46.07^{bc}	63.07^{b}	85.47^{b}
V_1I_3	48.73^{a}	65.47^{a}	89.40^{a}
V_2I_0	37.40^{g}	45.67^{h}	63.57^{ij}
V_2I_1	38.57^{fg}	47.53^{fg}	67.93^{h}
V_2I_2	43.27^{de}	54.87^{d}	75.07^{de}
V_2I_3	45.27^{bcd}	59.10^{c}	77.63^{c}
V_3I_0	35.17^{h}	46.53^{fgh}	61.80^{j}
V_3I_1	42.40^{e}	50.63^{e}	72.00^{fg}
V_3I_2	47.37^{ab}	64.70^{ab}	86.57^{b}
V_3I_3	49.17^{a}	66.23^{a}	90.47^{a}
V_4I_0	37.87^{g}	47.13^{fg}	64.47^{i}
V_4I_1	39.23^{fg}	48.23^{f}	71.13^{fg}
V_4I_2	42.80^{e}	53.73^{d}	73.57^{ef}
V_4I_3	44.23^{cde}	58.27^{c}	77.27^{cd}
$LSD_{0.05}$	2.104	1.977	2.523
CV(%)	6.83	7.19	10.53

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.1.2 Number of leaves plant^{-1}

4.1.2.1 Effect of variety

At 30, 60 and 90 DAP, significant variation was found on number of leaves plant^{-1} of different fodder grasses (Figure 4 and Appendix V). Results revealed that at 30 DAP, the highest number of leaves plant^{-1} (21.88) was observed from the variety V_3 (Pakchong grass) that was statistically similar with the variety V_1 (Napier grass) whereas the lowest number of leaves plant^{-1} (19.17) was found from the variety V_2 (Para grass) which was statistically similar with V_4 (German grass). At 60 DAP, the highest number of leaves plant^{-1} (26.13) was given by the variety V_3 (Pakchong grass) that was significantly similar with V_1 (Napier grass) whereas the lowest number of leaves plant^{-1} (25.15) was found from the variety V_2 (Para grass) that was statistically similar to V_4 (German grass). Similarly, at 90 DAP, the variety V_3 (Pakchong grass) gave the highest number of leaves plant^{-1} (38.08) that was significantly similar to the variety V_1 (Napier grass) whereas the variety V_2 (Para grass) showed the lowest number of leaves plant^{-1} (34.56) that was statistically similar to V_4 (German grass). Higher leaf number from the variety V_3 (Pakchong grass) followed by V_1 (Napier grass) suggests that this variety has the ability to produce more leaves (compared to other varieties) which might be contributed to higher biomass yield using.

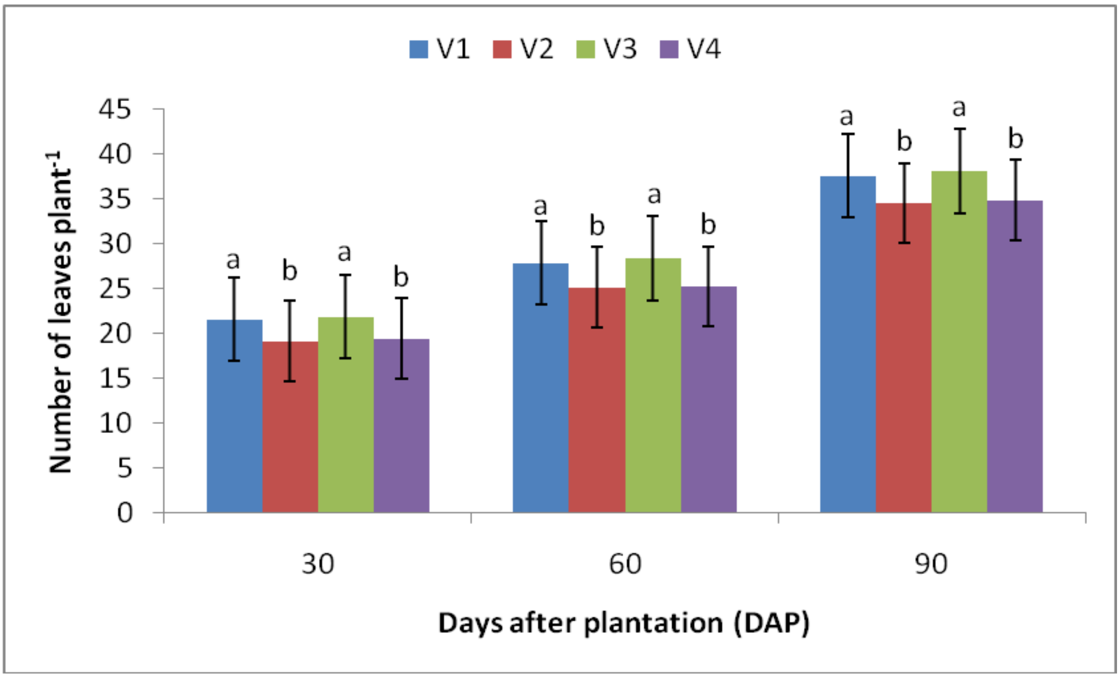


Figure 4. Number of leaves plant^{-1} of fodder crops as influenced by different varieties (NS = Non-significant)

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

4.1.2.2 Effect of irrigation

Significant influence was observed for number of leaves plant^{-1} of fodder grasses at different growth stages (Figure 5 and Appendix V). It was found at 30 DAP, the highest number of leaves plant^{-1} (26.13) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest number of leaves plant^{-1} (13.63) at 30 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different from other irrigation treatments. At 60 DAP, irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) represented the highest number of leaves plant^{-1} (33.95) that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest number of leaves plant^{-1} (17.75) at 60 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different to other irrigation treatments. Similarly, the highest number of leaves plant^{-1} (43.19) at 90 DAP was observed by the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) followed by I_2 (irrigation at 20 and 40 days of plantation) whereas the control irrigation I_0 (no irrigation) registered the lowest number of leaves plant^{-1} (27.12) at 90 DAP that was significantly different to other irrigation treatments. This result suggested that irrigation treatments helps to increase leaf number compared to control which is also supported by the findings of Alghobar *et al*. (2016).

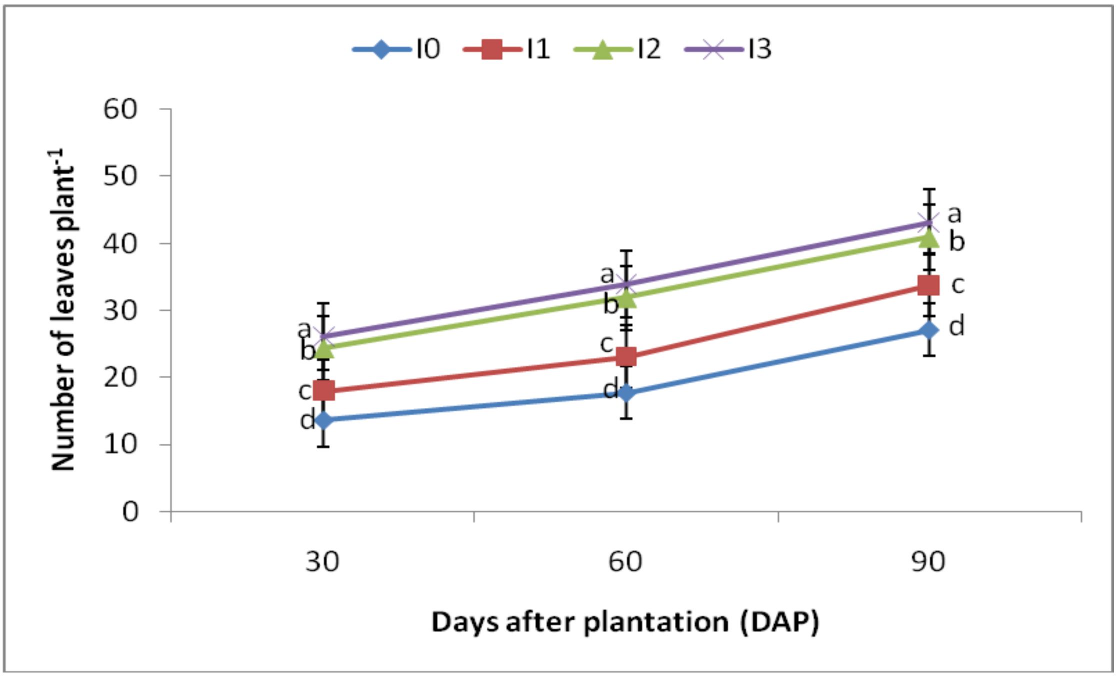


Figure 5. Number of leaves plant^{-1} of fodder crops as influenced by different irrigations treatments

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.1.2.3 Combined effect of variety and irrigation

Number of leaves plant^{-1} of fodder grasses at all growth stages was affected significantly due to combined effect of different variety and irrigation (Table 2 and Appendix V). Results indicated that the treatment combination of V_3I_3 gave the highest number of leaves plant^{-1} (28.60) at 30 DAP that was significantly similar to V_1I_2, V_1I_3 and V_3I_2 whereas the lowest number of leaves plant^{-1} (12.70) at 30 DAP was recorded from the treatment combination of V_1I_0 that was significantly similar to V_2I_0, V_3I_0 and V_4I_0. Again, at 60 DAP, the treatment combination of V_3I_3 gave the highest number of leaves plant^{-1} (36.47) that was significantly similar to V_1I_3 whereas the lowest number of leaves plant^{-1} at 60 DAP (16.87) was found from the treatment combination of V_1I_0 that was significantly similar to V_2I_0, V_3I_0 and V_4I_0. Likewise, at 90 DAP, V_3I_3 gave the highest number of leaves plant^{-1} (45.10) that was significantly similar to V_1I_2, V_1I_3

and V_3I_2 whereas V_1I_0 registered the lowest number of leaves plant^{-1} (25.83) at 90 DAP that was significantly similar to V_3I_0.

Table 2. Number of leaves plant^{-1} of fodder crops as influenced by combined effect of different variety and irrigations

Treatment	Number of leaves plant^{-1}		
	30 DAP	**60 DAP**	**90 DAP**
V_1I_0	12.70^{f}	16.87^{g}	25.83^{h}
V_1I_1	18.57^{de}	24.60^{e}	35.57^{d}
V_1I_2	26.70^{a}	33.87^{b}	44.20^{a}
V_1I_3	28.30^{a}	36.23^{a}	44.80^{a}
V_2I_0	14.50^{f}	18.27^{g}	27.90^{fg}
V_2I_1	17.00^{e}	20.63^{f}	30.93^{e}
V_2I_2	22.27^{bc}	30.00^{cd}	37.87^{c}
V_2I_3	23.97^{b}	31.70^{c}	41.53^{b}
V_3I_0	12.93^{f}	17.23^{g}	26.00^{gh}
V_3I_1	19.00^{d}	25.60^{e}	36.73^{cd}
V_3I_2	27.00^{a}	34.33^{b}	44.47^{a}
V_3I_3	28.60^{a}	36.47^{a}	45.10^{a}
V_4I_0	14.37^{f}	18.63^{g}	28.73^{f}
V_4I_1	17.23^{de}	21.57^{f}	32.10^{e}
V_4I_2	21.40^{c}	29.40^{d}	37.23^{cd}
V_4I_3	23.67^{b}	31.40^{c}	41.33^{b}
$LSD_{0.05}$	1.930	1.852	1.969
CV(%)	6.23	9.47	7.30

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.1.3 Number of branches plant^{-1}

4.1.3.1 Effect of variety

At different growth stages, non-significant variation was found for number of branches plant^{-1} of different fodder grasses (Figure 6 and Appendix VI). However, results revealed that at 30, 60 and 90 DAP, the highest number of branches plant^{-1} (5.68, 11.38 and 15.45, respectively) was observed from the variety V_3 (Pakchong grass) whereas the lowest number of branches plant^{-1} (5.44, 10.95 and 14.55, respectively) was found from the variety V_2 (Para grass). This result from the study suggested that varietal difference had no contribution on significant production of branches plant^{-1}.

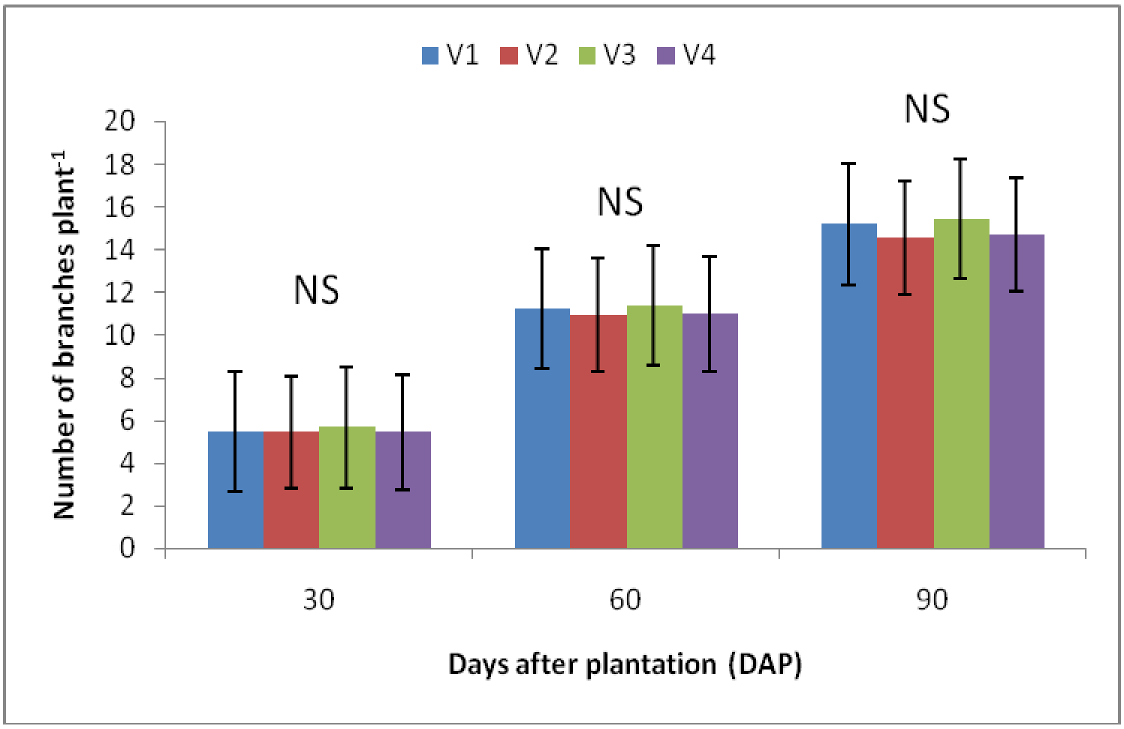


Figure 6. Number of branches plant^{-1} of fodder crops as influenced by different varieties

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

4.1.3.2 Effect of irrigation

Different levels of irrigation including control showed significant variation on number of branches plant^{-1} of fodder grasses at different growth stages (Figure 7 and Appendix VI). Results exposed that at 30 DAP, the highest number of branches plant^{-1} (6.61) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest number of branches plant^{-1} (4.14) at 30 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different from other irrigation treatments. At 60 DAP, irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) showed the highest number of branches plant^{-1} (13.07) was recorded from the irrigation treatment that was significantly varied to other irrigation treatments followed by I_2 (irrigation at 20 and 40 days of plantation). The lowest number of branches plant^{-1} (8.51) at 60 DAP was given by the control irrigation I_0 (no irrigation) that was significantly different to other irrigation treatments. Similarly, the highest number of branches plant^{-1} (17.47) at 90 DAP was observed by the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) followed by I_2 (irrigation at 20 and 40 days of plantation) whereas the control irrigation I_0 (no irrigation) registered the lowest number of branches plant^{-1} (12.13) at 90 DAP that was significantly different from other irrigation treatments. This result was in agreement with the findings of Suganthi *et al*. (2019) and Alghobar *et al*. (2016).

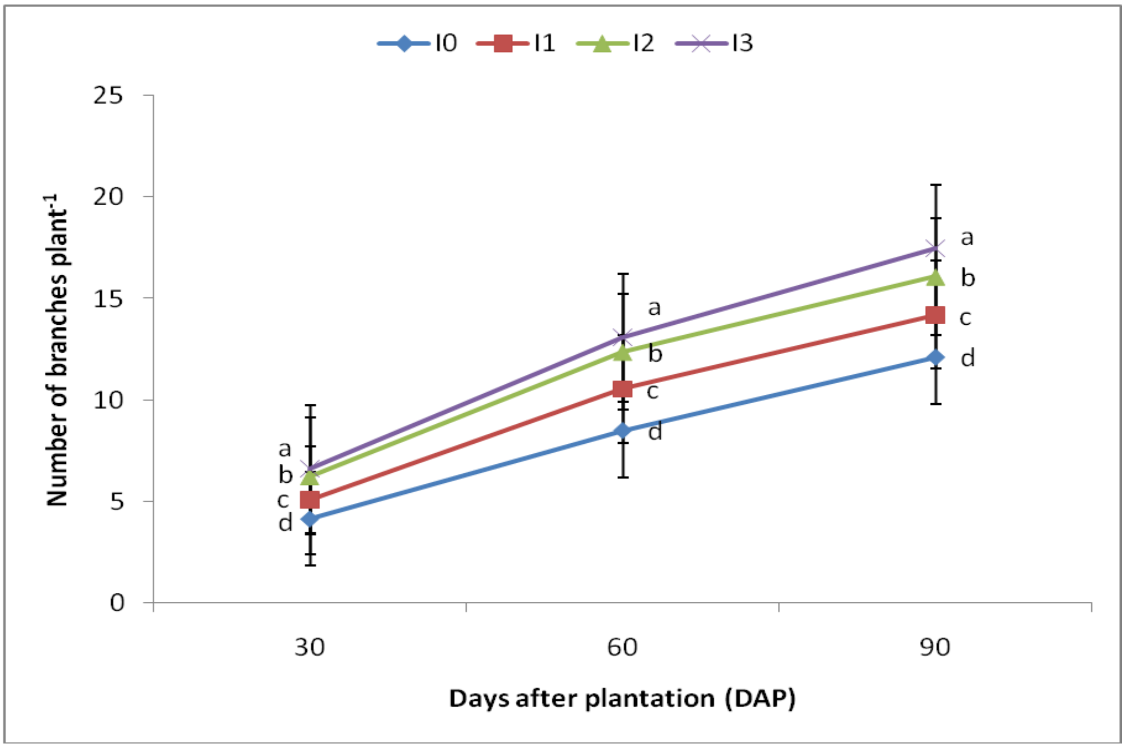


Figure 7. Number of branches plant^{-1} of fodder crops as influenced by different irrigations treatments

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.1.3.3 Combined effect of variety and irrigation

Combined effect of different variety and irrigation gave significant difference on number of branches plant^{-1} of fodder grasses at different growth stages (Table 3 and Appendix VI). Results indicated that the treatment combination of V_3I_3 gave the highest number of branches plant^{-1} (6.93) at 30 DAP that was significantly similar to V_1I_3 and V_3I_2 whereas the lowest number of branches plant^{-1} (3.40) at 30 DAP was recorded from the treatment combination of V_1I_0 that was significantly similar to V_3I_0. Again, at 60 DAP, the treatment combination of V_3I_3 gave the highest number of branches plant^{-1} (13.50) that was significantly similar to V_1I_3 and V_3I_2 whereas the lowest number of branches plant^{-1} at 60 DAP (7.70) was found from the treatment combination of V_1I_0 that was significantly similar to V_3I_0. Likewise, at 90 DAP, V_3I_3 gave the highest number of branches plant^{-1} (18.73) that was significantly similar to V_1I_3 whereas V_1I_0 registered the lowest number of branches plant^{-1} (10.87) at 90 DAP that was significantly similar to V_3I_0.

Table 3. Number of branches plant^{-1} of fodder crops as influenced by combined effect of different variety and irrigations

Treatment	Number of branches plant^{-1}		
	30 DAP	**60 DAP**	**90 DAP**
V_1I_0	3.40^{i}	7.70^{i}	10.87^{i}
V_1I_1	5.17^{g}	10.80^{ef}	14.57^{fg}
V_1I_2	6.53^{bc}	13.00^{bc}	16.83^{bc}
V_1I_3	6.83^{a}	13.33^{ab}	18.47^{a}
V_2I_0	4.70^{h}	9.17^{h}	13.00^{h}
V_2I_1	4.77^{h}	10.00^{g}	13.47^{h}
V_2I_2	5.93^{e}	11.87^{d}	15.23^{e}
V_2I_3	6.43^{cd}	12.77^{c}	16.50^{cd}
V_3I_0	3.63^{i}	7.83^{i}	11.17^{i}
V_3I_1	5.43^{f}	10.97^{e}	14.70^{ef}
V_3I_2	6.70^{ab}	13.23^{ab}	17.20^{b}
V_3I_3	6.93^{a}	13.50^{a}	18.73^{a}
V_4I_0	4.83^{h}	9.33^{h}	13.50^{h}
V_4I_1	4.87^{h}	10.40^{fg}	14.07^{g}
V_4I_2	5.83^{e}	11.43^{d}	15.10^{ef}
V_4I_3	6.23^{d}	12.67^{c}	16.17^{d}
$LSD_{0.05}$	0.253	0.447	0.540
CV(%)	7.32	4.42	11.57

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.2 Yield contributing parameters

4.2.1 Internode length (cm)

4.2.1.1 Effect of variety

Different varieties of fodder grasses showed significant influence on internode length (Table 4 and Appendix VII). Results revealed that the highest internode length (10.46 cm) was given by the variety V_3 (Pakchong grass) which was significantly differed to others followed by V_1 (Napier grass) whereas the lowest internode length (5.18 cm) was recorded from the variety V_2 (Para grass) which showed significant difference with other varieties. This result indicated that significant variation on internode length among varieties which suggested that the ability to increase internode length depends on varietal characters. Similar result was also observed by Bacchi *et al*. (2021).

4.2.1.2 Effect of irrigation

Internodes length of fodder grasses differed significantly due to different irrigation treatments including control (Table 4 and Appendix VII). It was observed that the highest internode length (8.92 cm) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) which was followed by the treatment I_2 (irrigation at 20 and 40 days of plantation). The lowest internode length (6.47 cm) was recorded from the control irrigation I_0 (no irrigation) that was significantly different to other treatments. The study suggests that higher levels of irrigation were contributed to increase potentiality of grasses and resulted higher internode length with three irrigation compared to low or no irrigation. Similar result was also observed by Norsuwan *et al*. (2014).

4.2.1.3 Combined effect of variety and irrigation

Treatment combination of different varieties of fodder grasses and irrigation treatments including control showed significant variation on internode length (Table 4 and Appendix VII). Results exhibited that the highest internode length (11.97 cm) was recorded from the treatment combination of V_3I_3 which was significantly similar to the treatment combination of V_1I_3 followed by V_1I_2 and V_3I_2. The lowest internode length (4.47 cm) was recorded from the treatment combination of V_2I_0 that was statistically similar to the treatment combination of V_4I_0.

4.2.2 Number of internodes tiller^{-1}

4.2.2.1 Effect of variety

Different varieties of fodder grasses had significant variation on number of internodes tiller^{-1} (Table 4 and Appendix VII). It was noted that the variety V_3 (Pakchong grass) gave the highest number of internodes tiller^{-1} (9.88) that was significantly similar to the variety V_1 (Napier grass). Reversely, the lowest number of internodes tiller^{-1} (5.70) was recorded from the variety V_2 (Para grass) which was significantly similar to the variety V_4 (German grass). This result suggested that the production capacity of internode in number was not same among different varieties and it differs significantly within variety to variety. This result was in agreement with the findings of Bacchi *et al*. (2021).

4.2.2.2 Effect of irrigation

Different levels of irrigation showed considerable influence on number of internodes tiller^{-1} of fodder grasses (Table 4 and Appendix VII). Results showed that the highest number of internodes tiller^{-1} (8.72) was given by the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly different to others followed by I_2 (irrigation at 20 and 40 days of plantation). Again, the lowest number of internodes tiller^{-1} (6.59) was recorded from the control irrigation I_0 (no irrigation) which was significantly different to other treatments. Under the present study, it was observed that higher internodes number per tiller achieved with higher frequency of irrigation and it was gradually decreased with decreasing irrigation levels and control treatment gave lowest result which suggests that higher levels of irrigation were contributed to increase potentiality of grasses. Similar result was also observed by Norsuwan *et al*. (2014).

4.2.2.3 Combined effect of variety and irrigation

Number of internodes tiller^{-1} of fodder grasses varied significantly due to combined effect of different varieties and irrigation (Table 4 and Appendix VII). The results showed that the highest number of internodes tiller^{-1} (10.77) was recorded from the treatment combination of V_3I_3 that was significantly similar to the treatment combination of V_1I_3 and V_3I_2. The lowest number of internodes tiller^{-1} (4.23) was recorded from the treatment combination of V_2I_0 that was significantly similar to the treatment combination of V_4I_0.

4.2.3 Fresh weight plant^{-1} (g)

4.2.3.1 Effect of variety

Varietal difference of different fodder grasses showed significant variation on fresh weight plant^{-1} (Table 4 and Appendix VII). The highest fresh weight plant^{-1} (365.50 g) was recorded from the variety V_3 (Pakchong grass) that was significantly different to others followed by V_1 (Napier grass) whereas the variety V_2 (Para grass) gave the lowest fresh weight plant^{-1} (92.50 g) that was significantly different to others. This result suggested that different varieties had different capacity to produce fresh weight. Similar result was also observed by Sarker *et al*. (2021) and Shedrack *et al*. (2019).

4.2.3.2 Effect of irrigation

Fresh weight plant^{-1} of fodder grasses varied significantly due to different irrigation treatments (Table 4 and Appendix VII). Results revealed that the highest fresh weight plant^{-1} (277.40 g) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly different to other treatments followed by I_2 (irrigation at 20 and 40 days of plantation) whereas the lowest fresh weight plant^{-1} (178.40 g) was recorded from the control irrigation I_0 (no irrigation). This result indicated that higher irrigation frequency had significant contribution to increase higher fresh weight compared to lower frequency of irrigation that was supported by the findings of Alghobar and Suresha, (2016).

4.2.3.3 Combined effect of variety and irrigation

Different treatment combination of variety and irrigation showed statistically significant variation on fresh weight plant^{-1} (Table 4 and Appendix VII). The highest fresh weight plant^{-1} (436.10 g) was registered from the treatment combination of V_3I_3 that was significantly similar to the treatment combination of V_1I_3 followed by V_3I_2. On the other hand, the lowest fresh weight plant^{-1} (71.67 g) was given by the treatment combination of V_2I_0 that was significantly similar to the treatment combination of V_2I_1. Similar result was also observed by Amal *et al*. (2010) and Cehchin (1998).

4.2.4 Dry weight plant^{-1} (g)

4.2.4.1 Effect of variety

Different varieties of fodder grasses showed significant influence on dry weight plant^{-1} (Table 4 and Appendix VII). It was found that the highest dry weight plant^{-1} (45.92 g) was recorded from the variety V_3 (Pakchong grass) that was significantly different to others followed by V_1 (Napier grass) whereas the lowest dry weight plant^{-1} (12.06 g) was recorded from the variety V_2 (Para grass). This result indicated that different varieties showed different levels of dry weight that was significantly different to each other which suggested that varietal difference contributed to significant variation in dry matter production.

4.2.4.2 Effect of irrigation

Dry weight plant^{-1} of fodder grasses differed significantly due to different irrigation treatments including control (Table 4 and Appendix VII). Results exhibited that the highest dry weight plant^{-1} (34.69 g) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) which differed significantly to other treatments. The lowest dry weight plant^{-1} (22.76 g) was recorded from the control irrigation I_0 (no irrigation) that was significantly different to other treatments. This result suggests that irrigation frequencies had considerable influence on dry matter production and resulted higher dry matter production with higher irrigation frequencies whereas low or no irrigation level showed lower performance on dry matter production. Supported result was also observed by Koech *et al*. (2016) and Alghobar and Suresha (2016).

4.2.4.3 Combined effect of variety and irrigation

Treatment combination of different varieties of fodder grasses and irrigation treatments including control showed significant variation on dry weight plant^{-1} (Table 4 and Appendix VII). It was observed that the highest dry weight plant^{-1} (54.73 g) was recorded from the treatment combination of V_3I_3 which was significantly differed to other treatment combinations followed by V_1I_3 and V_3I_2. On the other hand, the lowest dry weight plant^{-1} (9.87 g) was recorded from the treatment combination of V_2I_0 that was significantly similar to the treatment combination of V_2I_1, V_2I_2 and V_4I_0.

Table 4. Yield contributing parameters of fodder crops as influenced by different variety and irrigations

Treatment	Yield contributing parameters			
	Internode length (cm)	Number of internodes tiller^{-1}	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
Effect of variety				
V_1	10.29^{b}	9.61^{a}	347.20^{b}	43.44^{b}
V_2	5.18^{d}	5.70^{b}	92.50^{d}	12.06^{d}
V_3	10.46^{a}	9.88^{a}	365.50^{a}	45.92^{a}
V_4	5.41^{c}	5.92^{b}	117.10^{c}	14.85^{c}
$LSD_{0.05}$	0.154	0.286	13.301	1.627
CV(%)	5.36	4.41	12.69	8.59
Effect of irrigation				
I_0	6.47^{d}	6.59^{d}	178.40 ^{d}	22.76 ^{d}
I_1	7.48^{c}	7.44^{c}	213.50 ^{c}	26.97 ^{c}
I_2	8.48^{b}	8.36^{b}	252.80 ^{b}	31.85 ^{b}
I_3	8.92^{a}	8.72^{a}	277.40 ^{a}	34.69 ^{a}
$LSD_{0.05}$	0.157	0.291	12.883	1.630
CV(%)	5.36	4.41	12.69	8.59
Combined effect of variety and irrigation				
V_1I_0	8.33^{d}	8.83^{d}	266.70^{e}	33.87^{e}
V_1I_1	9.83^{c}	9.17^{d}	325.60^{d}	41.17^{d}
V_1I_2	11.10^{b}	9.83^{bc}	379.70^{c}	47.53^{c}
V_1I_3	11.90^{a}	10.60^{a}	416.70^{ab}	51.20^{b}
V_2I_0	4.47^{i}	4.23^{g}	71.67^{i}	9.87^{i}
V_2I_1	4.93^{gh}	5.50^{f}	81.11^{hi}	10.35^{hi}
V_2I_2	5.50^{f}	6.47^{e}	98.33^{gh}	12.83^{ghi}
V_2I_3	5.83^{e}	6.60^{e}	118.90^{fg}	15.17^{fg}
V_3I_0	8.43^{d}	9.03^{d}	281.10^{e}	35.46^{e}
V_3I_1	10.07^{c}	9.37^{cd}	343.60^{d}	43.23^{d}
V_3I_2	11.37^{b}	10.37^{ab}	401.10^{bc}	50.25^{bc}
V_3I_3	11.97^{a}	10.77^{a}	436.10^{a}	54.73^{a}
V_4I_0	4.63^{hi}	4.27^{g}	94.17^{hi}	11.83^{hi}
V_4I_1	5.10^{g}	5.73^{f}	103.90^{gh}	13.13^{gh}
V_4I_2	5.93^{e}	6.77^{e}	132.20^{f}	16.77^{f}
V_4I_3	5.97^{e}	6.90^{e}	138.10^{f}	17.68^{f}
$LSD_{0.05}$	0.308	0.573	24.561	3.242
CV(%)	5.36	4.41	12.69	8.59

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.3 Yield parameters

4.3.1 Fresh weight plot^{-1} (kg)

4.3.1.1 Effect of variety

Significant influence was found on fresh weight plot^{-1} of fodder grasses due to varietal difference (Table 5 and Appendix VIII). The highest fresh weight plot^{-1} (4.39 kg) was recorded from the variety V_3 (Pakchong grass) which differed significantly to other varieties followed by V_1 (Napier grass) whereas the lowest fresh weight plot^{-1} (1.11 kg) was recorded from the variety V_2 (Para grass). Similar result was also observed by Shedrack *et al*. (2019) and Sarker *et al*. (2021).

4.3.1.2 Effect of irrigation

Fresh weight of fodder grasses plot^{-1} differed significantly due to different irrigation treatments including control (Table 5 and Appendix VIII). Results indicated that the highest fresh weight plot^{-1} (3.33 kg) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) followed by I_2 (irrigation at 20 and 40 days of plantation) whereas the lowest fresh weight plot^{-1} (2.14 kg) was recorded from the control irrigation I_0 (no irrigation). Similar result was also observed by the findings of Jafarian *et al*. (2015) and Koech *et al*. (2016).

4.3.1.3 Combined effect of variety and irrigation

Treatment combination of different variety and irrigation treatments showed significant variation on fresh weight of fodder grasses plot^{-1} (Table 4 and Appendix VII). The highest fresh weight plot^{-1} (5.23 kg) was recorded from the treatment combination of V_3I_3 that was significantly similar to the treatment combination of V_1I_3. The lowest fresh weight plot^{-1} (0.86 kg) was recorded from the treatment combination of V_2I_0 which was significantly similar to the treatment combination of V_2I_1, V_2I_2 and V_4I_0.

4.3.2 Fresh yield ha^{-1} (t)

4.3.2.1 Effect of variety

Significant difference was found on fresh yield ha^{-1} among the varieties of fodder grasses (Table 5 and Appendix VIII). Results revealed that the highest fresh yield ha^{-1}

(8.12 t) was recorded from the variety V_3 (Pakchong grass) that was significantly different to others followed by V_1 (Napier grass). On the other hand, the lowest fresh yield ha^{-1} (2.05 t) was recorded from the variety V_2 (Para grass) that was significantly different to others. Varietal differences could be a major source of variation in biomass yield (Minson 1990). Sarker *et al*. (2021) reported significant difference on biomass yield of grasses due to varietal difference. Shedrack *et al*. (2019) also found similar result with the present study. Positive or complementary interactions between species are because of combinations of characteristics or functional roles that are beneficial for mixtures to increase productivity (Brooker *et al*. 2008).

4.3.2.2 Effect of irrigation

The result obtained from the study on fresh yield ha^{-1} affected significantly due to the different irrigation treatments (Table 5 and Appendix VIII). It was observed that the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) gave the highest fresh yield ha^{-1} (6.16 t) that was significantly different to others followed by I_2 (irrigation at 20 and 40 days of plantation). Again, the lowest fresh yield ha^{-1} (3.97 t) was recorded from the control irrigation I_0 (no irrigation) which was significantly different to other treatments. This result indicated that fresh yield was increased with increasing irrigation frequencies and resulted best yield with three irrigation compared to 2 or 1 or no irrigations. Supported result was also observed by Jafarian *et al*. (2015), Koech *et al*. (2016), Alghobar and Suresha (2016) and Canto *et al*. (2020).

4.3.2.3 Combined effect of variety and irrigation

The recorded data on fresh yield ha^{-1} influenced by different treatment combination of variety and irrigation was significant (Table 5 and Appendix VIII). Results indicated that the treatment combination of V_3I_3 gave the highest fresh yield ha^{-1} (9.69 t) that was significantly similar to the treatment combination of V_1I_3. On the other hand, the lowest fresh yield ha^{-1} (1.59 t) was given by the treatment combination of V_2I_0 that was significantly similar to the treatment combination of V_2I_1 and V_4I_0. Similar result was also observed by Amal *et al*. (2010) and Cehchin (1998).

Table 5. Yield parameters of fodder crops as influenced by different variety and irrigations

Treatment	Yield parameters	
	Fresh weight plot^{-1} (kg)	Fresh yield ha^{-1} (t)
Effect of variety		
V_1	4.17^{b}	7.72^{b}
V_2	1.11^{d}	2.05^{d}
V_3	4.39^{a}	8.12^{a}
V_4	1.41^{c}	2.60^{c}
$LSD_{0.05}$	0.163	0.201
CV(%)	8.70	8.67
Effect of irrigation		
I_0	2.14^{d}	3.97^{d}
I_1	2.56^{c}	4.75^{c}
I_2	3.03^{b}	5.62^{b}
I_3	3.33^{a}	6.16^{a}
$LSD_{0.05}$	0.158	0.203
CV(%)	8.70	8.67
Combined effect of variety and irrigation		
V_1I_0	3.20^{e}	5.93^{e}
V_1I_1	3.91^{d}	7.24^{d}
V_1I_2	4.56^{c}	8.44^{c}
V_1I_3	5.00^{ab}	9.26^{ab}
V_2I_0	0.86^{i}	1.59^{i}
V_2I_1	0.97^{hi}	1.80^{hi}
V_2I_2	1.18^{ghi}	2.18^{gh}
V_2I_3	1.43^{fg}	2.64^{fg}
V_3I_0	3.37^{e}	6.25^{e}
V_3I_1	4.12^{d}	7.64^{d}
V_3I_2	4.81^{bc}	8.91^{bc}
V_3I_3	5.23^{a}	9.69^{a}
V_4I_0	1.13^{ghi}	2.09^{ghi}
V_4I_1	1.25^{gh}	2.31^{gh}
V_4I_2	1.59^{f}	2.94^{f}
V_4I_3	1.66^{f}	3.07^{f}
$LSD_{0.05}$	0.321	0.548
CV(%)	8.70	8.67

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

4.4 Quality parameter

4.4.1 Protein content (%)

4.4.1.1 Effect of variety

Different varieties of fodder grasses showed significant influence on protein content (Table 6 and Appendix IX). Results showed that the highest protein content (12.45%) was recorded from the variety V_2 (Para grass) which was significantly different to other varieties followed by V_4 (German grass) whereas the lowest protein content (7.82%) was recorded from the variety V_1 (Napier grass). Varietal differences could be a major source of variation in quality of grass (Min-son 1990). Similar result was also observed by Sarker *et al*. (2021) and Shedrack *et al*. (2019) and reported that significant variation in crud protein content differed with varietal difference.

4.4.1.2 Effect of irrigation

Protein content of fodder grasses differed significantly due to different irrigation treatments including control (Table 6 and Appendix IX). The highest protein content (10.25%) was recorded from the irrigation treatment I_3 (irrigation at 20, 40 and 60 days of plantation) that was significantly similar to I_2 (irrigation at 20 and 40 days of plantation) whereas control irrigation I_0 (no irrigation) gave the lowest protein content (9.05%) that was significantly different to other treatments. This result indicated that crud protein percentage in fodder grasses was decreased with decreasing irrigation frequencies and control irrigation showed lease performance. This result suggests that irrigation treatment is very important to fodder grasses to increase protein content. Supported result was also observed by Bacchi *et al*. (2021) and Jafarian *et al*. (2015).

4.4.1.3 Combined effect of variety and irrigation

Treatment combination of different varieties of fodder grasses and irrigation treatments including control showed significant variation on protein content (Table 6 and Appendix IX). The highest protein content (12.93%) was recorded from the treatment combination of V_2I_3 that was significantly similar to the treatment combination of V_1I_2 followed by V_2I_0 and V_2I_1. The lowest protein content (7.45%) was recorded from the treatment combination of V_1I_0 that was significantly similar to the treatment combination of V_1I_3 and V_3I_0.

Table 6. Protein content of fodder crops as influenced by different variety and irrigations

Treatment	Protein content (%)
Effect of variety	
V_1	7.82d
V_2	12.45a
V_3	9.14c
V_4	9.89b
$LSD_{0.05}$	0.231
CV(%)	7.83
Effect of irrigation	
I_0	9.05c
I_1	9.83b
I_2	10.18a
I_3	10.25a
$LSD_{0.05}$	0.236
CV(%)	7.83
Combined effect of variety and irrigation	
V_1I_0	7.45^{i}
V_1I_1	7.94^{gh}
V_1I_2	8.23^{g}
V_1I_3	7.673^{hi}
V_2I_0	11.93^{b}
V_2I_1	12.22^{b}
V_2I_2	12.73^{a}
V_2I_3	12.93^{a}
V_3I_0	7.82^{ghi}
V_3I_1	9.42^{ef}
V_3I_2	9.51^{e}
V_3I_3	9.81^{de}
V_4I_0	8.98^{f}
V_4I_1	9.75^{e}
V_4I_2	10.24^{cd}
V_4I_3	10.59^{c}
$LSD_{0.05}$	0.463
CV(%)	7.83

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

V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass, V_4 = German grass

I_0 = Control (No irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation, I_3 = Irrigation at 20, 40 and 60 days of plantation

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the effect of irrigation management on growth and yield of fodder grasses during the period from October 2020 to January 2021. Four grass varieties *viz.* V_1 = Napier grass, V_2 = Para grass, V_3 = Pakchong grass and V_4 = German grass combined with four levels of irrigation including control *viz.* I_0 = Control (no irrigation), I_1 = Irrigation at 20 days of plantation, I_2 = Irrigation at 20 and 40 days of plantation and I_3 = Irrigation at 20, 40 and 60 days of plantation were laid out in a Randomized Complete Block Design (RCBD) with three replications.

Regarding varietal performance, at 30, 60 and 90 DAP, the highest plant height (43.53, 57.03 and 77.71 cm, respectively) and number of leaves plant^{-1} (21.88, 28.41 and 38.08, respectively) were observed from the variety V_3 (Pakchong grass) whereas the lowest plant height (41.03, 51.84 and 71.61 cm, respectively) was observed from the variety V_4 (German grass) and the lowest number of leaves plant^{-1} (19.17, 25.15 and 34.56, respectively) was recorded from the variety V_2 (Para grass). Non-significant variation was found for number of branches plant^{-1} among the varieties but at 30, 60 and 90 DAP, variety V_3 (Pakchong grass) gave the highest result (5.68, 11.38 and 15.45, respectively) whereas V_2 (Para grass) showed the lowest result (5.44, 10.95 and 14.55, respectively). Among the varieties and V_3 (Pakchong grass) registered the highest internode length (10.46 cm), number of internodes tiller^{-1} (9.88), fresh weight plant^{-1} (365.50 g), dry weight plant^{-1} (45.92 g), fresh weight plot^{-1} (4.39 kg) and fresh yield ha^{-1} (8.12 t) whereas V_2 (Para grass) showed the lowest internode length (5.18 cm), number of internodes tiller^{-1} (5.70), fresh weight plant^{-1} (92.50 g), dry weight plant^{-1} (12.06 g), fresh weight plot^{-1} (1.11 kg) and fresh yield ha^{-1} (2.05 t). But V_2 (Para grass) gave the highest protein content (12.45%) whereas V_1 (Napier grass) showed the lowest protein content (7.82%).

In terms of irrigation effect at 30, 60 and 90 DAP, I_3 (irrigation at 20, 40 and 60 days of plantation) showed the highest plant height (46.85, 62.27 and 83.69 cm, respectively), number of leaves plant^{-1} (26.13, 33.95 and 43.19, respectively) and number of branches plant^{-1} (6.61, 13.07 and 17.47, respectively) whereas control irrigation I_0 (no irrigation) gave the lowest plant height (36.29, 46.08 and 62.75 cm, respectively), number of leaves plant^{-1} (16.63, 17.75 and 27.12, respectively) and number of branches plant^{-1} (4.14, 8.51 and 12.13, respectively). Similarly, the highest internode length (8.91 cm), number of internodes tiller^{-1} (8.72), fresh weight plant^{-1} (277.40 g), dry weight plant^{-1} (34.69 g), fresh weight plot^{-1} (3.33 kg), fresh yield ha^{-1} (6.16 t) and protein content (10.25%) were recorded from I_3 (irrigation at 20, 40 and 60 days of plantation) whereas control irrigation I_0 (no irrigation) showed the lowest internode length (6.47 cm), number of internodes tiller^{-1} (6.59), fresh weight plant^{-1} (178.40 g), dry weight plant^{-1} (22.76 g), fresh weight plot^{-1} (2.14 kg), fresh yield ha^{-1} (3.97 t) and protein content (9.05%).

Consideration of the treatment combination, at 30, 60 and 90 DAP, the treatment combination of V_3I_3 showed the highest plant height (49.17, 66.23 and 90.47 cm, respectively), number of leaves plant^{-1} (28.60, 36.47 and 45.10, respectively) and number of branches plant^{-1} (6.93, 13.50 and 18.73, respectively) whereas control irrigation I_0 (no irrigation) gave the lowest plant height (34.76, 45.00 and 61.17 cm, respectively), number of leaves plant^{-1} (12.70, 16.87 and 25.83, respectively) and number of branches plant^{-1} (3.40, 7.70 and 10.87, respectively). Likewise, V_3I_3 also showed the highest internode length (11.97 cm), number of internodes tiller^{-1} (10.77), fresh weight plant^{-1} (436.10 g), dry weight plant^{-1} (54.73 g), fresh weight plot^{-1} (5.23 kg) and fresh yield ha^{-1} (9.69 t) whereas V_1I_0 gave the lowest internode length (4.47 cm), number of internodes tiller^{-1} (4.23), fresh weight plant^{-1} (71.67 g), dry weight plant^{-1} (9.87 g), fresh weight plot^{-1} (0.86 kg) and fresh yield ha^{-1} (1.59 t). Again, the highest protein content (12.93%) was recorded from V_2I_3 whereas V_1I_0 gave the lowest protein content (7.45%).

From the above results, it can be concluded that among the different treatment combinations of variety and irrigation, Pakchong grass with 3 Irrigations at 20, 40 and 60 days of plantation (V_3I_3) combination had best significant positive effect on growth and fresh yield of fodder grass compared to all other treatment combinations. But the highest percentage of protein was obtained from V_2I_3 compared to all other treatment combinations.

Recommendation

Considering the situation of the present study, further studies in the following areas may be suggested:

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other varieties may be used in future study.
3. Another frequencies of irrigations need to be considered before final recommendation.

CHAPTER VI

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

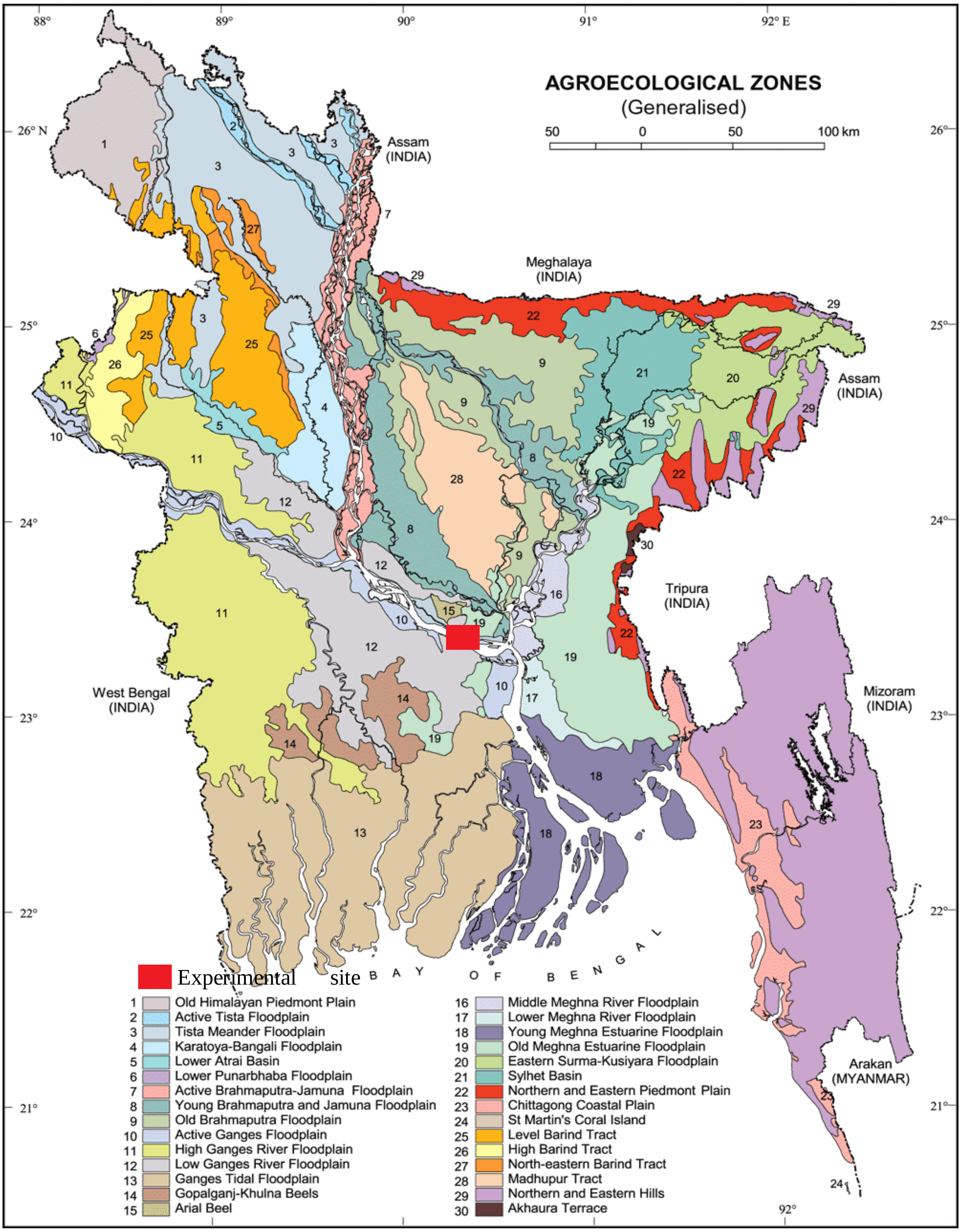

Figure 8. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from May 2020 to August 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	May	32.64	23.85	28.25	68.30	182.2
2020	June	27.40	23.44	25.42	71.28	190
2020	July	30.52	24.80	27.66	78.00	536
2020	August	31.00	25.60	28.30	80.00	348

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur 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	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis % sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of plant height of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of plant height		
		30 DAP	60 DAP	90 DAP
Replication	2	0.708	2.219	2.187
Factor A	3	16.736^{NS}	90.066*	140.882*
Factor B	3	272.43*	719.49*	1082.85*
AB	9	10.615**	21.871*	56.852*
Error	30	1.592	1.405	1.289

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of number of leaves plant^{-1} of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		30 DAP	60 DAP	90 DAP
Replication	2	1.063	0.512	0.069
Factor A	3	23.865*	35.364*	39.892*
Factor B	3	401.04*	690.65*	637.81*
AB	9	9.610**	8.809**	15.913*
Error	30	1.339	1.234	1.394

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

Appendix VI. Mean square of number of branches plant^{-1} of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}		
		30 DAP	60 DAP	90 DAP
Replication	2	0.206	0.724	0.859
Factor A	3	0.141^{NS}	0.528^{NS}	2.083^{NS}
Factor B	3	15.32*	50.163*	64.52*
AB	9	0.872**	1.679**	4.247*
Error	30	0.023	0.072	0.285

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of yield contributing parameters of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Internode length	Number of internodes tiller^{-1}	Fresh weight plant^{-1}	Dry weight plant^{-1}
Replication	2	0.306	0.063	0.885	0.389
Factor A	3	103.34**	62.26*	4947.67*	1397.7*
Factor B	3	14.302*	10.95*	2814.30*	133.36*
AB	9	0.906**	0.305**	180.008*	31.376*
Error	30	0.034	0.118	216.898	3.779

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

Appendix VIII. Mean square of yield parameters of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of yield parameters	
		Fresh weight plot^{-1}	Fresh yield ha^{-1}
Replication	2	0.001	0.001
Factor A	3	36.71*	125.96*
Factor B	3	3.285*	11.251*
AB	9	0.314**	1.075**
Error	30	0.037	0.058

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

Appendix IX. Mean square of protein content of fodder crops as influenced by different variety and irrigations

Sources of variation	Degrees of freedom	Mean square of protein content
Replication	2	0.031
Factor A	3	45.57*
Factor B	3	3.650**
AB	9	0.395**
Error	30	0.077

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

Plate 5. Initial growing stage of fodder grasses

Plate 6. Vegetative stage of fodder grasses

Plate 7. Field visit 1 of Supervisor before harvesting

Plate 8. Field visit 2 of Supervisor before harvesting

Plate 9. Sample harvesting of fodder grasses