YIELD AND QUALITY OF POTATO (*SOLANUM TUBEROSUM L.*) AS INFLUENCED BY SPLIT APPLICATION OF NPK AND IRRIGATION

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CERTIFICATE

*This is to certify that the thesis entitled, "**YIELD AND QUALITY OF POTATO (SOLANUM TUBEROSUM L.) AS INFLUENCED BY FERTILIZER AND IRRIGATION FREQUENCY**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **ANIKA,** Registration no. **19-10372** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:

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Dedicated to

My

Beloved Parents

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YIELD AND QUALITY OF POTATO (*SOLANUM TUBEROSUM L.*) AS INFLUENCED BY FERTILIZER AND IRRIGATION FREQUENCY

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from September-2020 to February-2021, to study the yield and quality of potato (*Solanum tuberosum L.*) as influenced by fertilizer and irrigation frequency. The experiment consisted of two factors, and followed split plot design with three replications. Factor A. Different fertilizer application frequency (3) *viz:* F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018] were placed in the main plot and Factor B. Different irrigation frequency (3) *viz:* I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP) were placed in the sub-plot. Among different treatment of fertilizer application frequencies, the F_3 treatment produced the highest tuber yield (21.89 t ha^{-1}), specific gravity (1.084 g cm^{-3}), starch content (13.90 %), as well as the highest yield of graded A (0.40 %) and B (29.56 %) of potatoes. Regarding various irrigation frequencies, the highest tuber yield $plant^{-1}$ (296.47 g), tuber yield (22.48 t ha^{-1}), starch content (13.90 %), highest dry matter content of $tuber^{-1}$ (19.80 %), and highest graded A (0.53%) and B (30.84 %) type of potato yield were all found in the I_2 treatment. In terms of combination results, the F_3I_2 treatment combination showed the best results, recording the highest tuber yield (23.50 t ha^{-1}), starch content (13.90 %), dry matter content $tuber^{-1}$ (20.80 %), starch content (14.80 %) and yielding the highest A (0.72 %) and B (32.13%) graded of potatoes. Therefore, it was indicated that cultivation of potato through application of recommendation dose of fertilizer through split 3 times: N, K and 2 times P (F_3) combined with four irrigation (20,30,45 and 60 DAP) (I_2) would help to enhanced yield and qualities of potatoes.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is widely grown around the world because of its rich nutrition, ease of cultivation, and high yield (Wang *et al*., 2020). It is now the fourth most important food crop in the world, after wheat, rice, and maize, covering 19.3 million ha and producing 388.2 million tons (Waqas *et al*., 2021). It is now grown in more than 100 countries and feeds more than a billion people worldwide (Islam *et al*., 2020). In Bangladesh production of potato is gradually increasing. Bangladesh experienced much progress in area, production and yield of potato in the last decade, as its area, production and yield raised to 461 thousand ha, 9605 thousand MT and 20.8 MT/ha in 2019-20 from 435 thousand hectares, 7930 thousand MT and 18.25 MT/ha in 2009-10, with growth rates 6%, 21% and 14%, during the period, respectively. It has happened due to the suitable environment and using high yielding varieties in potato production. As currently production exceeds demand, Bangladesh started exporting fresh potato in the world market and exported 45000 MT of fresh potato in 2019-20 (Sabur *et al*., 2021). Annual potato consumption per capita also increased and reached 25.66 kg in 2016 from 23.65 kg in 2010, bringing the growth rate 8.5% during the only six-year period (HIES, 2016).

Potato tubers provide a large amount of dietary carbohydrates and protein, most of which are represented by starch (60–80% of dry matter), reducing sugars and organic acids, whose content is significantly affected by variety, soil environment and their interactions (Romano *et al*., 2018). Currently, potato yields have stagnated between 5 and 9 tons per hactares compared to the achievable farmer yields of about 20 tha^{-1} (Otieno, 2019a). The low yields could be attributed to soil infertility, improper use of fertilizer, foliar pests and diseases, use of poor quality tuber seeds and low yielding varieties, untimed weed control, and within-season droughts (Mugo *et al*., 2020). Therefore, it is a key measure to improve the quality and yield of potato tubers to identify different agronomic managements such as fertilizer and irrigation frequency and their interaction effects.

Potato being nutrients exhaustive crop has higher requirement of nitrogen, phosphorus, potassium and other nutrients (Kahsay, 2019), however, the balanced nutrition at planting ensures a good start for the potato crop and higher productivity. Compared with other crops, potatoes have a high demand for N and K nutrients. In terms of nutrient mining, potatoes remove about 4 kg N and 6.5 kg K, per ton of tubers harvested (Otieno and Mageto, 2021). A limited supply of N and K severely affects potatoes at the vegetative and tuber bulking stage, significantly reducing tuber yields. Hence for optimal production, soils must be replenished with N and K. Importantly, the demands for these nutrients vary depending on the stage of growth. For instance, the stage of highest macronutrient demand by various potato cultivars is during initial tuber bulking and varies between 42 to 70 days after planting (Otieno and Mageto, 2021). Thus fertilizer application method influence tuber size and quality of potato.

During topdress application, N should be applied in splits to reduce losses from leaching, volatilization, and erosion processes (Wang, 2019). Split application of N also ensures that the nutrient is made available only when needed, thereby increasing N-use efficiency (Belete *et al*., 2018). In terms of timing and method of K application, just like phosphorus, potato crops benefit more when the application is made either before or at the time of planting. Split application of potassium enhances N uptake and protein synthesis resulting in better foliage growth (Habtam *et al*., 2018). It also enhances root permeability and water uptake and, hence, improving water use efficiency of potato plant. This application should be done early but not later than 30-60 days before planting (Otieno, 2019a).

Potato needs frequent irrigation for its good growth and higher yield. Water deficit in the early stage of potato growth mainly resulted in a decrease in potato leaf area and tuber number, while water deficit in the late stage reduced the degree of leaf area reduction but had significant effects on tuber size and quality (Avila-Valdes *et al*., 2020). Early stress is the most unfavorable to nodulation and expansion and the decrease in tuber yield is the result of the decrease in the carbon assimilation rate (Aliche *et al*., 2020). Water deficiency causes physiological disorder of potato and a decrease in dry matter and tuber starch content (Carli *et al*., 2014). There is a need to enhance the soil moisture content by the different strategies which influence the WUE of crop.

Adaptation of the improved agro techniques such as irrigation frequency creates the favourable microclimatic condition (Kingra and Harleen, 2017). Irrigation frequency in any crop depends upon soil type, method of planting, location as well as crop varieties (Salih *et al*., 2018). The salient features of any improved method of irrigation is the controlled application of the required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants (Ulsido and Alemu, 2014). The requirement for water irrigation of potato plants are diverse in different plant growth stages *viz*; tubers initiation and tubers bulking are the more sensitive stages in the plant growth life (Nasir and Toth, 2022). A suitable irrigation frequency can establish a balance between soil moisture and oxygen conditions in the crop root zone, reduce root soaking, and maintain a high soil matric potential in the rhizosphere to reduce plant water stress throughout the growing season (Zhang *et al*., 2019). Thus, optimizing irrigation frequency and water-application rate could help maximize crop yield and WUE. The observation that several previous studies have shown that high yield and WUE result from suitable irrigation frequency indicates that a frequent and uniform water supply is important for meeting the water requirements of plants and maximizing crop yield and WUE (Liu *et al*., 2019; Zhang *et al*., 2019). Therefore by considering the above facts, the research work was carried out with the following objectives:-

- To answer the influence of split application of N,K and P fertilizers on yeild and quality of potato.
- To find out the effect of irrigation frequency on the yield and quality of potato.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to investigate the yield and quality of potato as influenced by fertilizer and irrigation frequency, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of fertilizer application method

Vidushi *et al*. (2022) found significant effect of different nitrogen and potash doses application on various parameters on potato cultivation. The treatment T_8 (50% RDK + Spray of K_2SO_4 @ 2% at 30 DAP) was found to be the best for improving growth characters, while treatment T_4 (RDF160:100:120kg NPK/ha) was found best in terms of yield parameters. Based on the results of present investigation, it could be concluded that application of RDF 160: 100: 120 kg NPK/ ha can still be adopted by the farmers but with split applications of nitrogen and potassium as recommended dose for commercial cultivation of potato under present climatic conditions to achieve higher net returns per unit area provided all other agronomic package of practices are followed.

Mugo *et al*. (2020) carried out an experiment to assessment of soil fertility and potato crop nutrient status in central and east ern highlands of Kenya and reported that the low yields of potato could be attributed to soil infertility, improper use of fertilizer, foliar pests and diseases, use of poor quality tuber seeds and low yielding varieties, untimed weed control, and within-season droughts.

Priyanka *et al*. (2020) carried out an experiment to determination of nitrogen split doses on quality features and nitrogen conservation of potato and reported that the highest dry matter content (19.85%), protein content (7.62 %) and nitrogen content (1.22%) in tuber was recorded with the treatment T_6 (6 (50% basal N + 25% top dressing at 25 DAP + two foliar spray @ 2% urea at 40 & 55 DAP) whereas, maximum specific gravity (1.03 g cc^{-1}), nitrogen content in haulm and whole plant (2.74 % and 3.95 %) and nitrogen uptake by haulm and whole plant (64.73 kg/ha and 155.58 kg/ha) was recorded with the treatment T5 (50% basal N + 25% top dressing at 25 DAP + one foliar spray @ 2% urea at 40 DAP). The effect of split application of nitrogen-on-nitrogen uptake by haulm was found non-significant. Split nitrogen application treatments have shown a positive impact on nitrogen use efficiency and nitrogen apparent recovery. Highest nitrogen use efficiency (170.76%) and NAR (59.20%) of potato plants was found with the treatment T_2 (50% basal N + one foliar spray@ 2% urea at 25 DAP).

Singh *et al*. (2020) reported that the potassium requirement for potatoes is much higher than that of grains. Being a shallow root crop, the effectiveness of using potassium fertilizers on potatoes varies from 50 to 60 percent. Potassium nutrition plays an important role in increasing the potato yield, either due to the formation of large tubers or the increase in the number of tubers per plant. Among the integrated nutrient management in potatoes, farmyard manure improves the absorption and availability of potassium for potato plants. Potassium protects against frost and drought stress in plants and reduces the incidence of diseases or pests. Potassium availability also decreases the concentration of reducing sugar and improves the colour and quality of potato chips. Potassium sulfate improves potato quality better than sources of potassium chloride.

Sriom *et al*. (2020) reported that decrease in specific gravity was due to increase in water content of the tuber, which was influenced by nitrogen levels because high levels of nitrogen leads to more moisture uptake, which ultimately increases the water content of tubers.

Verma (2020) reported that the growth, yield attributing characters and yield was influenced by split application of nitrogen and significantly increased values were obtained. Among seven treatments, 50 % basal N of RDF + 25 % top dressing at 25 DAP + two foliar spray @ 2 % urea at 40 and 55 DAP was found best regarding growth, tuber yield and B-C ratio.

Bera *et al*. (2019) was carried out a field experiment to study the effect of different doses of nitrogen and potassium fertilizer on growth and yield of potato and found that highest growth attributes and yield namely plant height (36.17 cm), LAI (3.12), CGR (40.04g ma^{-2} day^{-1}), NAR (6.04g ma^{-2} day^{-1}) and LAD (132.53 days) and tuber yield (28.917 t ha^{-1})

were recorded in case of the treatment where N and K_2O applied as basal + 1/4 at 28 and 42 DAP @ 200:150:150 N:P2O5:K_2O kg ha^{-1} . Amongst the ten treatments adopted in the experiment, the highest net return ha-1 (Rs.78860.31) and highest return per rupee investment (1.83) were obtained from the treatment where N and K_2O were applied as basal + 1/4th at 28 and 42 DAP @ 200:150:150 N:P_2O5:K_2O kg ha^{-1}.

Bista and Bhandari, (2019) reported that growth parameters such as plant height, leaf area and chlorophyll% was positively correlated with potassium application. Potassium alleviated stresses of frost and drought and reduced incidence of diseases like late blight, black scurf and hollow heart. Potassium also decreased the reducing sugar content and improved chips color and quality. Similarly, potassium application before harvest was found to increase storage life of potato tubers. Furthermore, potassium application significantly increased the yield of potato tubers and quality parameters such as Vitamin C content and specific gravity. Source of potassium and method of potassium application also affected growth, yield and quality parameters. Soil application of potassium in splits coupled with foliar spay was found to perform better. Optimum dose of potassium was recommended for economic tuber production.

Job *et al*. (2019) reported that the split application of K fertilizer had little influence on plant nutrition and tuber yield and quality.

Abarna and Srinivasan (2018) was conducted a field experiment at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirapalli to study the impact of split application of nitrogen and potassium on growth and yield of cotton during summer 2017 and indicated that split application of nitrogen and potassium upto boll developmental stage (90 DAS) significantly influenced the growth and yield of cotton. Application of 50 per cent N and K as basal+25 per cent N and K each at 60, 75 and 90 DAS (T5) was superior in terms of growth parameters. Skipping N and 50 per cent K as basal+25 per cent N and 50 per cent K at 45 DAS+25 per cent N at 60 DAS+25 per cent N at 75 DAS+25 per cent N at 90 DAS (T8) recorded the highest seed cotton yield.

Ayyub *et al.* (2018) reported that the overall, qualitative characters of tubers and yield enhanced with split fertilizer application as compared to all fertilizer applied once at planting time whereas, there was no significant difference between tuber nitrogen, potassium, phosphorus and protein contents.

Corrêa *et al.* (2018) carried out a study aimed to evaluate the effect of split application of potassium (K) fertilizer on the production and quality of sweet potatoes and reported that the production characteristics of the roots presented a significant interaction between the factors doses of potassium and application types (parcelaments). Finally, better results were obtained when potassium was applied 50% at planting and 50% as topdressing.

Irungbam *et al.* (2018) reported that the increase in total number of tubers per plot with the increased levels of split applications of nitrogen and potash may be due to the fact that total number of tubers mainly depends on number of stolons per plant, therefore, the potato plants receiving the higher and split applications of these nutrients may had more number of stolons and ultimately this resulted into higher number of tubers per plot.

Ahmed *et al*. (2017) reported that unbalanced use of chemical fertilizer is a problem in the intensive cropping systems on the Central part of Bangladesh. Proper nutrient management is essential to maximize potato production and sustain agricultural production while minimizing negative impacts on the soil fertility. They also concluded from their study that the highest tuber yield (35.75 t/ha) was found from T_5= Four splits (1 /4 nitrogen at 5 DAP, 1 /4 at the 20 DAP, 1 /4 at the 35 DAP and1 /4 at the 50 DAP) treatment. The lowest tuber yield was obtained from control treatment.

El-Hadidi *et al.* (2017) reported that significant increase in no. of tubers/plant, average tuber weight (g) and tuber yield was observed with 150 kg N fed^{-1} over control treatment. Increase in tuber yield with 96 kg K_2O fed^{-1} was statistically significant compared to other treatments. The quality parameters like dry matter, specific gravity, total carbohydrate, reducing sugar and starch contents were improved with both nitrogen and K application.

Sati *et al*. (2017) was conducted a field trial with the objective to examine the effect of different potash levels and methods of application on yield and quality of potato and included observations for yield parameters i.e., number and yield of tubers and quality parameters i.e., specific gravity, dry matter content, starch content and protein content of tubers were recorded. There was significant effect found under various potash treatments in terms of number and yield of tubers. The split application (basal + spray) of potash gave the maximum tuber number (12.5) and yield (1274.5 g) per plant. As per the quality is concerned, the findings revealed that the quality parameters of potato crop (viz., starch content, protein content and specific gravity) were significantly influenced by different split potash levels which indicates the superiority of split application of potash to that of basal application and no application.

Choudhary *et al*. (2016) evaluated the ten farm trials on black soils (27-44 % clay) and confirmed that nitrogen uptake efficiency (NUE) improved by 9.9 % over farmers practice. Band placement of double the dose of N as basal and than the recommended two splits as basal and at earthing-up further boosted the initial growth and improved the cane yields and NUE by 22 and 11 % over farmers practice.

Sati *et al.* (2016) carried out an experiment to study the effect of dose and method of potash application on production behaviour of potato and reported that the number and yield of tubers per plant as well as per plot were increased when potato crop was nourished with K_2SO_4. The results indicated that increasing potash application rate and split application of potash i.e., basal + foliar, gave better response than that of control and single application (basal only). The increase in number of tubers may be due to the fact that number of tubers mainly depends on number of stolons per plant. Therefore, if potato plant has more number of stolons with higher number of haulms, it ultimately results into higher number of tubers. On the other hand, the increase in tuber yield might be due to improved soil fertility, growth and better potash uptake by potato tuber which resulted in better growth of photosynthetic organs, translocation of nutrients and photosynthates to developing plant parts.

Rens *et al*. (2015) reported that nitrogen (N) is one of the nutrients that exerts the greatest influence on the growth and development of plants under different environmental conditions it is also the key factor in the yield and quality of potatoes and it is not easy to control. Rational application of nitrogen fertilizer is one of the most important components of achieving a high yield.

According to Zelelew and Ghebreslassie (2015) highest tuber weight (1.14 kg plant^{-1}) and yield (49.38 tones ha^{-1}) are recorded from Ajiba treated with 300 kg K_2O ha^{-1}. They further revealed that there is a promising profit return by investing more on potassium application upto 300 kg K_2O ha^{-1}. So they recommended that potassium fertilizers should be introduced to optimize productivity in Hamelmalo area, Eritrea.

Zeru and Mesfin (2015) studied three varieties (Ajiba, Zafira and Picasso) and five potassium levels (0, 75, 150, 225 and 300 kg K/ha) along with all possible interactions were u. Data was collected on yield and tuber quality parameters. The result of the study indicated that there were significant variations in the performances of varieties in terms of yield and quality parameters in which Ajiba was found to be more responsive and high yielding. Tuber no of tuber in terms of diameter, tuber weight per plant, total yield, total soluble solids, specific gravity and tuber moisture content showed significant differences due to the application of potassium.

Zelelew *et al.* (2016) experimented on potato growth with five K doses (0, 75, 150, 225, and 300 kg K_2O ha^{-1}) and reported that parameters like plant height, aerial stem number, and leaf number per plant increased with the increasing K levels from 0 kg to 150 kg ha^{-1}.

Banjare *et al.* (2014) reported that the increase in potato yield attributing parameters like number of stolon, fresh and dry weight of tuber per plant and tuber yield/ha increased with increased fertilizer application rate and the fertiliser split application method. The results was an overall increase in the average fresh tuber weight, tuber N and NO_3-N concentrations, and decreased specific gravity as nitrogen fertilization increased.

Wani *et al*. (2014) reported that plant height and dry matter accumulation was higher with the split application of potassium as compared to single basal application.

El-Ghany *et al*. (2013) reported that potassium fertilizer in the form of potassium sulphate @ 50 kg/fed at 30 DAS along with 3.0% K_2O recorded the highest values of plant height (cm), chlorophyll content and flag leaf area (cm_2) than control treatment (without foliar application of potassium).

Moniruzzamman *et al*. (2013) reported that the increase in number of tuber $plant^{-1}$ supplemented with nitrogen fertilizer may be due to the availability of mineral nitrogen to potato plant root, which ultimately resulted in better root growth and increased mineral absorption that lead to increase number of tuber $plant^{-1}$ and this in turn increased total yield. This might be due to positive response shown by yield characters to potassium could be directly linked by well development of photosynthetic and increased physiological activities leading to more assimilates and improved the translocation accumulation of sugars in development of tubers.

Muhammed *et al.* (2013) tested 6 levels of K, i.e. 50,100, 150, 200, 250, 300 kg K_2O ha^{-1} from SOP to determine its effects on some physio-morphological features of potato cultivar "Desiree". They reported that SOP at the level of 150 kg ha^{-1} gave the best results in most of the parameters like plant height, number of tubers per plant, tuber weight per plant, yield per hectare, TSS, tuber dry weight per plant while, extremely high dose of SOP gave poor results as compared to control for some of the parameters. Number of aerial stems per plant, number of leaves per plant, specific gravity of tubers and tuber dry mass did not show any significant change with change in K levels.

Yourtchi *et al.* (2013) illustrated that the highest amount of plant height, leaf and stem dry weight, Leaf Area Index (LAI), fresh and dry weight of tuber, total tuber weight, total number of tuber, tuber diameter, nitrogen percent of tuber, potassium percent of tuber and phosphorous percent of tuber were found from application of 150 kg N ha^{-1}.

Tesfaye *et al.* (2013) reported that specific gravity is the measure of choice for estimating dry matter (DMC) and starch content (SC) and ultimately for determining the processing quality of potato varieties. Potatoes of high dry matter contents, more typically expressed as high specific gravity, are important in processing industry in terms of finished product yield, oil uptake and quality.

Ati and Nafaou (2012) found that increasing the rate of application of potassium fertilizer (K_2SO_4) to soil resulted increase in vegetative growth of potato plant.

Sun *et al.* (2012) was conducted an experiment to assess the effects of N application time on dry matter accumulation in foliage and tubers, as well as on marketable tuber ratio, dry matter concentration, and specific gravity of the Chinese cultivar KX 13 and reported that reported that application time of nitrogen (N) fertilizer can significantly influence the yield and quality of potato tubers.

Bansal and Trehan (2011) opined that plants supplied with K_2SO_4 translocate more photosynthates from leaves and stems to the tubers than the plants supplied with KCl. Soil application of K accompanied by foliar spray could be far better for the higher yields in potato. Similarly, split application of potassium was found to perform better than basal application.

Indirajith and Natarajan (2011) conducted a field experiment at Annamalainagar, Tamil Nadu, to evaluate the split applications of NPK on seed cane productivity of sugarcane. The application of recommended dose of nitrogen and potassium on 30, 60, 90,120 and 150 days after planting along with the recommended dose of phosphorus applied 50 per cent as basal and 50 per cent as top dress on 30 days after planting recorded significantly the higher mean shoot population (1,14,000 ha^{-1}), cane length (231.5 cm), individual cane weight (1.19 kg) and seed cane yield (95.08 ha^{-1}).

Kumar *et al.* (2011) found that N application time and crop geometry did not influence emergence, shoot number, plant height, leaf number and leaf area index. Total as well as process grade tuber number, yield and process grade tuber weight also remained unaffected due to crop duration and time of N application. In contrast tuber number and productivity declined with wider spacing. Although excess soil or foliar N application late in the season resulted in lowering the tuber specific gravity and dry matter. Economic analysis indicated that application of 270 kg N/ha in two equal splits at planting and earthing-up gave 7.5% more returns over 3 splits + 1 foliar spray of urea. Crop duration of 110 days and wider spacing were optimum for harnessing the yield potential and realizing higher returns and benefit cost ratio.

Patel *et al*. (2011) was conducted a field experiment during rabi seasons of 2006-07 and 2007-08 to study the effect of fertigation of nitrogen and potash under different methods of irrigation on yield of processing grade tubers of potato cv. Kennebec and reported that F_3 (100% recommended dose of N and K) treated plot recorded significantly higher number and yield of processing grade A and B tubers, but it was at par with F_2 (75% recommended dose of N and K) treatment.

Jamaati-e-Somarin *et al*. (2010) showed that variation in tuber yield due to nitrogen treatments were related to the tuber weight increment.

Cerny *et al.* (2010) reported that nitrogen and potassium are important essential macronutrients which play important role in growth and development of potato crop. Inadequate N fertilization leads to poor potato growth and yield while excessive N application leads to delayed maturity, poor tuber quality, and occasionally a reduction in tuber yield.

The importance of splitting N applications was emphasized by Jaamati *et al*. (2010) who showed that dividing total nitrogen into two or more applications would assist in enhancing the nutrient efficiency, promote optimum yield and mitigate the loss of nutrients and hence bigger potatoes. High nutrient availability early in the growing season does not influence tuber initiation but overall improvement in yield occurred as an additional advantage of splitting nitrogen application.

Khan *et al.* (2010) reported increase in number of tubers with increasing rates of K application up to 150 kg/ha and increase in potato tuber yield with K application whereas there was further enhancement in yield with additional foliar application of K, respectively. They also reported that starch content of tuber was also increased with the increasing levels and split application of potash as compared to that of control or basal application only. It might be due to the better vegetative growth and role of potassium in starch formation and its translocation to tubers which resulted in more reserve food accumulation in tubers.

Najm *et al*. (2010) conducted field experiment to evaluate the effect of the cattle manure (5, 10, 15 and 20 t/ha), nitrogen fertilizer (50, 100 and 150kg N/ha) and their interaction on potato growth in Iran. At the 75 day after emergence, dry weight of shoots, leaf area index (LAI) and plant height were recorded. Results showed that, dry weight of shoots, LAI and plant height increased linearly and very significantly in response to the application of manure and nitrogen fertilizer.

Sandhu *et al.* (2010) found an increase in total and processing grade tuber yield with nitrogen application up to 200 kg N/ha. Chip colour darkened with the application of nitrogen, while dry matter content and tuber flesh firmness were maximum at 200 kg N/ha. The content of reducing sugars, sucrose, free amino acids and total phenols increased with nitrogen application of 200 kg N/ha was the optimum dose.

Zamil *et al.* (2010) have found that the higher dose nitrogen (254 kg N ha^{-1}) results in significantly higher total tuber number in Potato tubers.

Guler (2009) also reported that the maximum tuber yield was obtained when the crop received 300 and 254 kg nitrogen per ha, respectively. They also noted a reduction in tuber yield when N was applied above the aforementioned rates. The yield reduction due to excess rates of N may be explained by the fact that excessive N application stimulates shoot growth more than tuber growth which may result in deterioration of canopy structure and physiological conditions.

Gunadi (2009) reported that plant height was not significantly affected by the potassium (K) fertilizer sources and application methods. However, the sources and application methods of K fertilizer affected canopy cover, crop cover weeks (CCW), tuber dry weight (DW), and total plant DW at 10 WAP. Potatoes supplied with K_2SO4 either in split or split combined with foliar application had significantly higher percent canopy cover, CCW, tuber DW, and total plant DW than those supplied with K fertilizer in single application. Potatoes supplied with K_2SO_4 had a higher tuber yield compared to those fertilized with KCl, especially under split or split combined with foliar application. To attain the same level of tuber yield as in the split combined with foliar application method, the rate of K_2SO_4 should be increased from 150 to 250 kg K_2O ha^{-1} when using single application. It is therefore suggested that K_2SO_4 for potatoes should be used in split application combined with foliar application.

Hassanpanah *et al.* (2009) reported that potato at the beginning of its growth requires a lot of available nitrogen. Nitrogen is needed to take up carbon. Sufficient nitrogen increases both plant growth and leaf surface and tuber size and causes crop to become tolerant to leaf blot disease.

Nikardi (2009) conducted an experiment to determine the response of potato to different source of potassium (potassium chloride and potassium sulphate) at different rates of application 150 and 250 kg per hectare and application method as single, split, and split combined with foliar application. In the single application, potassium was applied at planting, while in the split application, potassium was applied half at planting and the rest at 6 weeks after planting. In the split combined with foliar application treatment, potassium fertilizer was applied half at planting, a quarter at six weeks after planting and another quarter by foliar spraying at seven, eight and nine weeks after planting and reported that potassium sulphate applied in split or split combined with foliar application produced significantly higher tuber yield, and tuber dry weight than those supplied with potassium fertilizer in single application.

Hopkins *et al.* (2008) reported that Potatoes require a steady supply of nutrients. Deficiencies or fluctuations of soluble nutrients (especially N) cause poor vine health, increased pathogen and insect susceptibility, reduced tuber yields, and diminished tuber quality. Potatoes require high amounts of fertilizer not only because of high nutrient demand, but also because they have a shallow, inefficient rooting system to explore soil nutrient from wider surface area.

Cucci and Lacolla (2007) that dry matter percentage increased shifting from the control to the application of 200 kg N ha^{-1} and 50 kg P ha^{-1} from 23.0 to 26.2% and decreased at the highest N level, without any difference being observed with the change in the P rate.

2.2 Effect of irrigation frequency

Djaman *et al*. (2021) revealed that irrigation management can affect the quality of the production and the chemical composition of tubers during the storage period which is particularly critical for the chip potato industry. Potato dry weight is constituted mainly by starch and small quantities of sugars, fiber, protein, and ash. Potato tuber content in sucrose, glucose, and fructose are important factors affecting the color of the processed products such as French fries and chips in potatoes.

Satognon *et al*. (2021) carried out an experiment to know the effects of supplemental irrigation on yield, water use efficiency and nitrogen use efficiency of potato grown in mollic Andosols. The treatments comprised two irrigation treatments of full supplemental irrigation (FI) and rainfed production (RF) and four N levels of four N levels of 0 (N0), 60 (N1), 90 (N2) and 130 kg N/ha (N3). Experiment result showed that total tuber yield, marketable tuber yield and NUE were significantly ($P < 0.001$) affected by irrigation × N-fertilisation while WUE was only affected ($P < 0.001$) by N-fertilisation. The highest total tuber yield, 58.28 tonnes/hectare (t/ha), was recorded under FI combined with N3. Treatment FI significantly increased marketable tuber yield by approximately 125.58% in all N treatments compared to RF. The highest NUE of potato (236.44 kg/kg of N) was obtained under FI combined with N_3 but not significantly different from the NUE of potato obtained under FI with N_2. N-fertilisation N3 produced the highest WUE of 14.24 kg/m^3. Significant correlation was obtained between tuber yield and number of tubers/plant ($r = 0.75$, $P < 0.001$), NUE ($r = 0.95$, $P < 0.001$) and WUE ($r = 0.72$, $P < 0.001$).

Dash *et al.* (2018) reported for frequent irrigation at 30 mm CPE for maximum yield in potato.

Salih *et al*. (2018) carried out an experiment to evaluate the impact of irrigation interval on quality and tuber yield in potato cultivars. In this study there are four irrigation intervals (3,5,7 and 9 days) used by furrow irrigation method which subjected in complete randomized design (CRD) with three replications. The potato tuber production in 3 day interval showed highest percentage also protein and starch content was recorded highest in both year of cultivation, but the abscisic acid was affected by more irrigation which in 3 day interval irrigation the rate was less than other. Also in 5 day interval irrigation the rate was acceptable because there is no significant difference in terms of tuber yield, protein and starch content if compare with 3 day interval irrigation in particular for those area faced restricted in using water irrigation.

Nagaz *et al.* (2017) found that if management is not practiced properly, application of irrigation water with low/poor quality water may compound existing problems of field with soil salinity.

Amer *et al.* (2016) found that total tubers yield was significantly increased with increasing water supply and they reported that percentage of tubers dry mater was significantly increased with decreasing soil moisture and irrigation water rates.

Behera *et al.* (2015) conducted a field experiment at the Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar during summer season of 2015. The results revealed that the irrigation at 0.8 IW:CPE ratio recorded significantly higher plant growth.

Irfan *et al*. (2015) reported that yield attributes viz. total number, weight (grade wise), total weight of tubers hill^{-1}, plot^{-1} and ha^{-1} was highest under 1.0 IW/ CPE ratio over 0.8 IW/CPE ratio. Number of all grade of tubers was found to be non-significant due to effect of moisture regimes. quality parameters were did not affected due to moisture regimes.

Abubaker *et al*. (2014) reported an increase in specific gravity with an increase in irrigation frequency. Early appropriate stages irrigation increases tuber dry matter and continuous or late-season irrigation can reduce potato dry matter content.

Kumar (2014) conducted a field experiment on mungbean (*Vigna radiata* L.) during summer2013 at Crop Research Centre, Rajendra Prasad Agricultural University, Pusa, Samastipur, Bihar. Two irrigations at 20 and 40 days after sowing recorded significantly higher yield attributes than rainfed and one irrigation at 40 days after sowing.

Pejic (2014) reported that the highest yield of potato was obtained on the irrigation variant of 70% of FWC (43158 kg ha^{-1}). The amounts of water used on evapotranspiration under irrigation (ETm) and non-irrigation conditions (ETa) ranged from 451.4 to 501.4 mm, and 373.4 to 381.2 mm, respectively. The values of IWUE and ETWUE varied from 71.4-112.5 kg ha^{-1} mm^{-1} and 67.0 do 91.9 kg ha^{-1} mm^{-1} respectively. As the highest values of yield, IWUE and ETWUE coefficients of potato were obtained on the irrigation variant of 70% of FWC that level of soil moisture represents the time when to start with irrigation if potato is grown in a soil with medium soil texture, under climatic conditions of the Vojvodina region.

Yadav and Singh (2014) conducted a field experiment to study the effect of four different irrigation schedules based on IW: CPE ratio at Faizabad (Uttar Pradesh). Maximum seed yield was obtained with 1.0 IW: CPE ratio followed by 0.8 and 0.6 IW: CPE ratio. All the growth attributes *viz.*, plant height, dry matter and leaf area index were highest under more frequently irrigated water regimes.

Mahima and Mrinal (2013) concluded that, irrigation applied at critical stages significantly recorded highest tuber yield (18.03 t ha^{-1}). However irrigation applied at 25 mm CPE recorded significantly the highest yield of both B grade (25-50 g) and C grade (50-75 g) tubers. Both B and C grades has higher market price and mostly preferred by people than A grade and D grade size tubers. Likewise, application of mulch significantly 24.04% higher yield over non mulch condition.

Sadawarti *et al.* (2013) reported that plant emergence was not significantly affected due to either the various levels of irrigation or mulching.

Verma *et al.* (2013**)** conducted a field experiment in two consecutive rabi and summer seasons (October‑July) during 2007-08 and 2008-09 at New Delhi to study the effect of irrigation and nitrogen management on productivity of potato (*Solanum tuberosum* L.)

and their residual effect on succeeding maize (*Zea mays* L.). Results indicated that among the irrigation regimes, irrigation at 60 mm CPE recorded significantly the highest growth characters, yield attributes and total tuber and biological yields over irrigation at 80 and 100 mm CPE.

Aksic *et al.* (2012) reported that the potato plants under different irrigation rates, *i.e.*, irrigated by three treatments with irrigation (soil matrix potential of 20, 30 and 40 kPa) as well as control. Irrigation schedule was determined by tensiometers. They found that total yield increased with increasing irrigation rate.

Badr *et al*. (2012) reported that water deficiency caused a reduction of yield by reducing growth of crop canopy and biomass that may be due to the potato crop had low tolerance for water stress.

Tyagi *et al.* (2012) conducted a field experiment on sandy loam soil during winter season of 2004-05 and 2005-06 at Indian Agricultural Research Institute, New Delhi. The treatments comprised of 5 irrigation levels (irrigation at critical stages of potato (*Solanum tuberosum* L.), irrigation at critical stages of French bean (*Phaseolus vulgaris* L.), and irrigation at 0.8, 1.2 and 1.6 IW/CPE ratio) as main plots and 3 cropping systems (sole potato, sole French bean and potato + French bean in 2:3 row ratio). Irrigation at IW/CPE ratio of 1.6 produced the highest tuber yield followed by irrigation at 1.2 IW/CPE ratio, while the lowest tuber yield was achieved with irrigation at 0.8 IW/CPE ratio.

Amer (2011) reported that total yield increased under high level of soil moisture on squash.

Saikia (2011) observed that moisture stress, especially at the most critical stages like stolon formation, tuber formation and tuber development, results sharp decline in potato productivity.

Shuhao *et al.* (2011) showed that, WUE of potato increased significantly in the supplemental irrigation treatment of 45 mm and decreased with increasing of irrigation amount. WUE and irrigation water use efficiency (IWUE) of potato were higher with supplemental irrigation at the seedling than the tuber expanding stage. WUE and IWUE were the highest under the 45 mm of irrigation at the seedling stage.

Ati *et al*. (2010) studied the yield of potato (*Solanum tuberosum L*.), under regular deficit irrigation. Soil moisture content with depth, potato yield, crop evapotranspiration (ET), water use efficiency (WUE) and crop water productivity (CWP) were measured. Results showed that, the yield of potato were 34.5, 34.3, 28.2 and 30.2 t ha^{-1} for control treatment (irrigate restabilising field capacity when 60% of the available water was depleted), T_1 (no irrigation during vegetative growth stage), T_2 (no irrigation during tubulisation stage) and T_3 (no irrigation during bulking and tuber enlargement), respectively for the first season, while in the second one equalled 36.7, 36.2, 30.0 and 31.2 T ha^{-1}. Values of cumulative evapotranspiration were 441-391 mm and 428.7- 373.7 mm for the two seasons, respectively. The corresponding WUE were highest 8.33 and 9.21 kg m^{-3} under T_1 treatment at vegetative growth stage of the two seasons.

Dibal *et al*. (2010) reported that irrigation at 20 mm CPE had the highest seasonal crop water use.

Masoudi (2010) carried out an study to know the effect of different irrigation intervals on the yield and plant characteristics of potato (*Solanum tuberosum* L.), a field exoeriment was carried out in split plot arrangements using randomized complete block design with three replications at research field station, faculty of agricultural, the university of Urmia, in 2008 growing season. Experimental treatments were included irrigation intervals at four levels: (6) I_0, 10(I_1), (14)I_2 and (18) I_3 day assigned to main plots, and growth stages at two levels: 50% emergence to 50% flowering (GS1) and 50% flowering to physiological maturity (GS2) randomized in sub-plots. Results showed that tuber fresh yield, tuber dry yield, mean of tuber fresh weight.$plant^{-1}$, stem diameter, plant height, tuber size and dry matter at 1%, and the number of stem and relative water content in 5% probability level were affected by different irrigation intervals. However, irrigation intervals had no significant effect on mean of tuber dry weight.$plant^{-1}$, specific weight and cell membrane stability.

Mukherjee *et al*. (2010) reported that, fruit yield increased with the increase in irrigation frequencies. Maximum fruit yield (39.5 Mg ha^{-1}) was obtained under CPE 25 frequency and it significantly declined by 8 % and 30%, respectively under CPE 50 and when crop was grown under rainfed condition.

Patel *et al.* (2010) stated that application of irrigation at 1.0 IW:CPE ratio to frenchbean registered significantly highest mean seed yield and straw yield over 0.8 and 0.6 IW:CPE ratio.

Chawla *et al*. (2009) conducted the field studies to observe the effect of mulch and drip irrigation on quality of potato (*Solanum tuberosum* L.) and they reported that, the highest yield of 312.3 q ha^{-1} was obtained under HDI- High Drip Irrigation 1.0 IW/CPE ratio treatment against a yield of 238.7 q ha^{-1} obtained for the conventionally irrigated mulched treatment.

Kulathunga *et al.* (2009) found that the nodulation and growth parameters were significantly higher with the three day irrigation schedule, while the maximum yield was obtained at the six day irrigation schedule.

Fereres and Soriano (2007) reported that deficit irrigation, widely reported as a valuable strategy for dry regions is particularly important for crops which are frequently subject to chronic water shortages. Due to chronic water shortage and soil degradation hazards in irrigated areas, there is a need to develop strategies that may help to save water and control salinity.

Kataria and Chandel (2007) conducted a field experimet that optimum moisture regime (irrigation at IW / CPE ratio of 1.0) resulted significantly higher tuber yield, growth and yield attributes. Rajmash was grown successfully as relay crop in spring potato resulting in significantly higher potato equivalent yield and net returns.

Patel and Rajput (2007) reported that water deficiency caused a reduction of yield by reducing growth of crop canopy and biomass that may be due to low tolerance of potato for water stress.

Samey (2006) reported that the specific gravity and percentage of tuber dry matter in two season were significantly increased with decreasing irrigation rates, i.e., irrigation by 50% of the evapotranspiration compared with irrigation by 75, 100 and 125% of the evapotranspiration, while the lowest value of water supply, i.e., irrigation by 125% of the evapotranspiration also it ranged from 21.0 % to 23.5 %..

Patel and Patel (2001) carried out an experiment including two potato cultivars (Kufri Badshah and TPS C-3), four irrigation levels (1.00, 1.25, 1.50 and 1.75 (IW/CPE) and three nitrogen levels (180, 220 and 260 kg N ha^{-1}) during 1995-96 in Gujarat, India. They found that, the CU of water increased (440 mm) with increase in water supply 1.75 IW/CPE followed by 1.50 IW/CPE. An increasing trend in CU was observed with an increase in growth.

CHAPTER III

MATERIALS AND METHODS

The field experiment "Yield and quality of potato (*Solanum tuberosum L.*) as influenced by fertilizer and irrigation frequency " was conducted during *Rabi* season of 2020-2021. The detail of this experiment regarding soil, climate, weather and method adopted for the present investigation are summarized in this chapter under appropriate heads.

3.1 Experimental period

The experiment was conducted during the period from September-2020 to February-2021.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was carried out at Sher-e-Bangla Agricultural University's Agronomy farm (SAU). The experimental site is located 8.6 meters above sea level at a latitude and longitude of 23°77 N and 90°33 E, respectively. In Appendix I Map of Bangladesh's AEZ, the experimental site has been highlighted for easier understanding.

3.2.2 Climate and weather

The experimental site's climate was subtropical, with the winter season lasting from November to February, the pre-monsoon period, also known as the hot season, lasting from March to April, and the monsoon season lasting from May to October . Appendix-II contains meteorological information about the temperature, relative humidity, and rainfall during the experiment period that was gathered from the Bangladesh Meteorological Department's Climate Division in Sher-e-Bangla Nagar, Dhaka.

3.2.3 Soil characteristics

The soil of experimental plot was medium deep black having uniform topography. In order to know the physiochemical properties of the experimental site the soil sample to the depth of 0-30 cm were randomly collected from the experimental site before planting and further analyzed. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in Appendix-II.

3.3 Experimental materials

BARI Alu-25 (Astorix) was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. The origin of this variety came from The Netherlands and in the year of 2005 it was then officially released for cultivation of potato. Plant straight and average 3-4 stem /plant, leaf large, green and bushy, plant structure and leaf orientation is attractive, potato oval shape to tall, medium to large size, skin red and smooth, flesh pale yellow, shallow eye, sprout violet color and hairy, and crop duration 90-95 days are the main characteristics of this variety. It was cultivated in Rabi season and the average yield between 25-30 tha^{-1}.

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot there was fertilizer treatment and in sub plot there was different irrigation frequency treatment. There were 9 treatment combinations and 27 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5 Experimental treatment

There were two factors in the experiment namely different fertilizer application frequency and different irrigation frequency as mentioned below:

Factor A. Different fertilizer application *viz:* (3)

F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP)

F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP)

F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP)

Factor B. Different irrigation *viz:* (3)I_1= Three times irrigation (20, 30 and 60 DAP)

I_2= Four times irrigation (20, 30, 45 and 60 DAP)

I_3= Five times irrigation (20, 30, 45, 60 and 75 DAP)

3.6 Tuber collection

For conducting the present experiment the tuber of the test crop *i.e*., BARI Alu-25 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.7 Land preparation

Initially the field was prepared with the help of tractor drawn implement. After giving one deep ploughing the experimental field was cross harrowed and levelled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually for sowing the subsequent crops of the experimental study.

3.8 Fertilizer application

Potato, having a sparse root system gives good response to applied nutrients. Potato crop requires a large amount of nutrients- nitrogen, phosphorus and potassium for good growth and development of the potato crop. Different doses of fertilizers were applied according with par treatment requirement.

3.9 Tuber treatment

Tubers were inoculated @ 25 g kg^{-1} of tuber with slurry of Azotobacter and Bavistin solution and tubers were dried in shade for 30 minutes before planting.

3.10 Planting of tubers

Seed tubers of variety BARI Alu-25 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Well sprouted seed tuber were selected and placed in marked row at 60 cm and maintain 30 cm plant spacing. To protect crop from sucking pest at initial stage, granules of Thimet 10 G were applied uniformly in row @ 10 kg ha^{-1}. Irrigation was given immediately after planting of tubers.

3.11 Intercultural operations

3.11.1 Weeding and mulching

To keep the plots free of weeds, manual weeding was done when needed. For easy aeration and to store soil moisture as needed, the soil's crust was broken and then mulched. Mulching also assisted in preventing the growth of weeds such as Bathua plants (*Chenopodium album*). These two procedures were properly carried out without endangering the health of the test crop.

3.11.2 Gap filling

The plant population was maintained by gap filling at 20 days after planting.

3.11.3 Earthing up

Earthing up was done twice during growing period. The first earthing up was done at 25 DAP on 29 November, 2020 and second earthing up was done after 15 days of first earthing up on14 December, 2020.

3.11.4 Irrigation

Irrigation was given as per the schedule of irrigation treatment . A common irrigation was given before planting and 10 days after planting for good emergence of tuber and establishment of crop. Later irrigation was given as per the treatment.

3.11.5 Plant protection

Additional than cutworm, no other insects were discovered to be detrimental to potato growth. During the last stage of field preparation, Furadan 5G was applied @ 10kg ha^{-1} to protect soil-borne insects. To suppress the cutworm, Dursban was applied @ 2ml L^{-1} after 20 DAP. As a defense against potato late blight (*Phytophthora infestans*), Dithane M-45 was applied @ 2g L^{-1} at 10-day intervals. In some plots, poisonous bait was employed to keep rats away from the tubers.

3.12 Haulm cutting

Haulm cutting was done at maturity level on 15 February, 2021. After haulm cutting the tubers were kept under the soil for skin hardening.

3.13 Harvesting

Harvesting was done at physiological maturity rates. First of all, border harvested. Then net plot was marked. Harvesting was done on 28th February 2021 manually with the help of kudal.

3.14 Collection of data

The following parameters were recorded and their mean values were calculated from the sample plants.

i. Number of tubers plant^{-1}
ii. Dry weight of tuber plant^{-1}
iii. Tuber yield plant^{-1}
iv. Tuber yield t ha^{-1}
v. Dry matter content
vi. Starch content
vii. Grading of potato
viii. Specific gravity

3.15 Procedure of data collection

i. Number of tubers plant^{-1}

Numbers of tubers from three randomly uprooted plants was counted and mean value was computed to indicate the number of tubers per plant.

ii. Dry weight of tuber plant^{-1}

For dry weight of potato samples after sundried kept for 24 hours an oven at 60°C for drying to a constant weight. Finally, the dry matter was recorded treatment wise in each plant and average was worked out.

iii. Tuber yield plant^{-1}

The weight of tubers plant^{-1} was calculated from the average of 5 selected plants randomly from each unit plot at harvest and was expressed in gram.

iv. Tuber yield t ha^{-1}

The yield of tuber received from each net plot was recorded and converted on hectare basis by multiplying with hectare factor.

v. Dry matter content

Tuber samples were collected from each treatment. The samples were dried in an oven at 72 degrees Celsius for 72 hours after being peeled. The weights of tuber flesh dry matter content % were then recorded. The dry matter percentage of tuber was calculated using the formula below.

$$\text{Dry matter content (\%)} \quad \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

vi. Specific gravity

It was measured by using the following formula

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$$

vii. Starch content

The starch content of potato tuber was estimated using the standard procedure (Sawhney and Randhir, 2001) and expressed in percentage on dry weight basis.

viii. Grading of potato

Potato that were taken from single plot were separated by number and weight considering the diameter of the potato. The diameter of each sample was recorded using a measurement scale and categorized into the following classes: >55 mm, 45-55 mm, 28-40 mm and <28 mm and converted to percentages. Potato tuber greater the 28 mm were estimated as marketable yield and tuber that range from 28-55 mm were measured as seed tuber. Whereas, chips potato and French fry potato was graded as 55-75 mm and >75 mm, respectively. Undersized tubers i.e., <28 mm and oversized tubers i.e., >55 mm, were graded as a non-seed tuber. For grading, a particular type of frame (square shaped) was used. In this experiment according to the potato size (%) tuber were graded in the following different grades, i.e., A grade (> 55 mm), B grade (40 to <55 mm), C grade (28 to < 40 mm) and D grade (< 28 mm), were weighted grade wise separately.

3.16 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 software. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

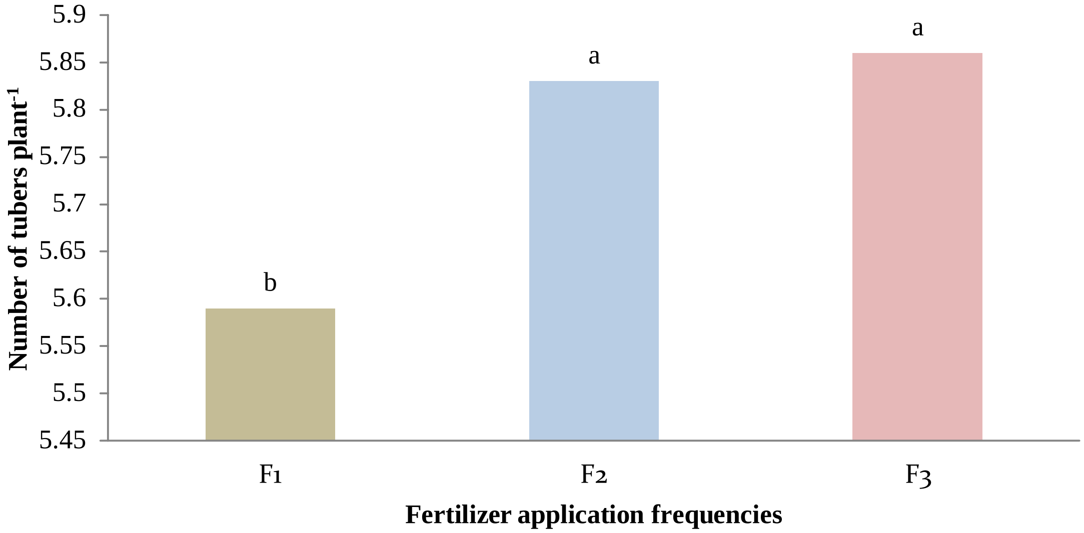
RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on yield and quality of potato as influenced by fertilizer and irrigation frequency. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Number of tubers plant^{-1}

Effect of fertilizer application frequency

The experimental results showed that number of tuber plant^{-1} of potato was significantly influenced by different fertilizer application frequency (Figure 1). The highest number of tuber plant^{-1} of potato (5.86) was observed in F_3 treatment which was statistically similar with F_2 (5.83) treatment. Whereas the lowest number of number of tuber plant^{-1} of potato (5.59) was observed in F_1 treatment. The effect of fertilizers managements on tuber plant^{-1} of potato was due to the increased availability of nutrients, especially nitrogen and phosphorus. Nitrogen increases the growth of aerial organs, phosphorus increases the energy transfer for the growth of plant vegetative organs, in general, it improves photosynthesis and thus increased tuber plant^{-1} of potato. Sati *et al*. (2017) reported that deferent method of fertilizer application significantly influenced the tuber number of potato. Zamil *et al*. (2010) have found that the higher dose nitrogen (254 kg N ha^{-1}) results in significantly higher total tuber number in Potato tubers.

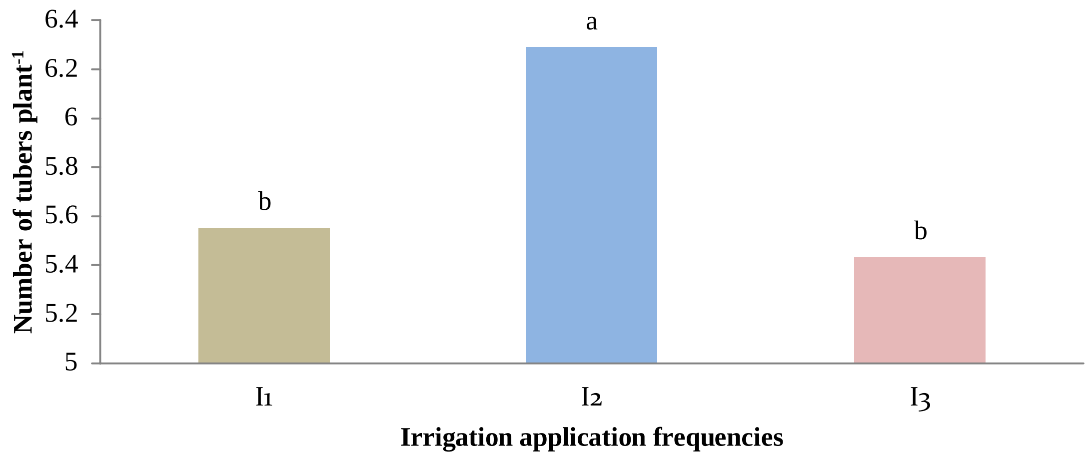


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018]

Figure 1. Effect of different fertilizer application frequency on number of tubers plant^{-1} of potato

Effect of irrigation frequency

The outcomes of the experimental result demonstrated that different irrigation frequencies showed significant variation in respect of number of tuber plant^{-1} of potato (Figure 2). Experimental result revealed that the highest number of tuber plant^{-1} of potato (6.29) was observed in I_2 treatment. Whereas the I_3 = Five times irrigation (20, 30, 45, 60 and 75 DAP) treatment had the lowest number of number of tuber plant^{-1} of potato (5.43) which was statistically similar with I_1 (5.55) treatment because excess water used in I_3 treatment and roots are damaged. The condition of the plant under water stress is reduced by appropriate irrigation. Delaying watering will result in water stress, reduced soil moisture, and a reduction in tuber development, all of which have an effect on the growth of dry matter production, tuber number plant^{-1} and the plant's yield. Irfan *et al*. (2015) reported that yield attributes viz. total number, weight (grade wise), total weight of tubers hill^{-1}, plot^{-1} and ha^{-1} was highest under 1.0 IW/ CPE ratio over 0.8 IW/CPE ratio.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 2. Effect of different irrigation application frequency on number of tubers plant^{-1} of potato

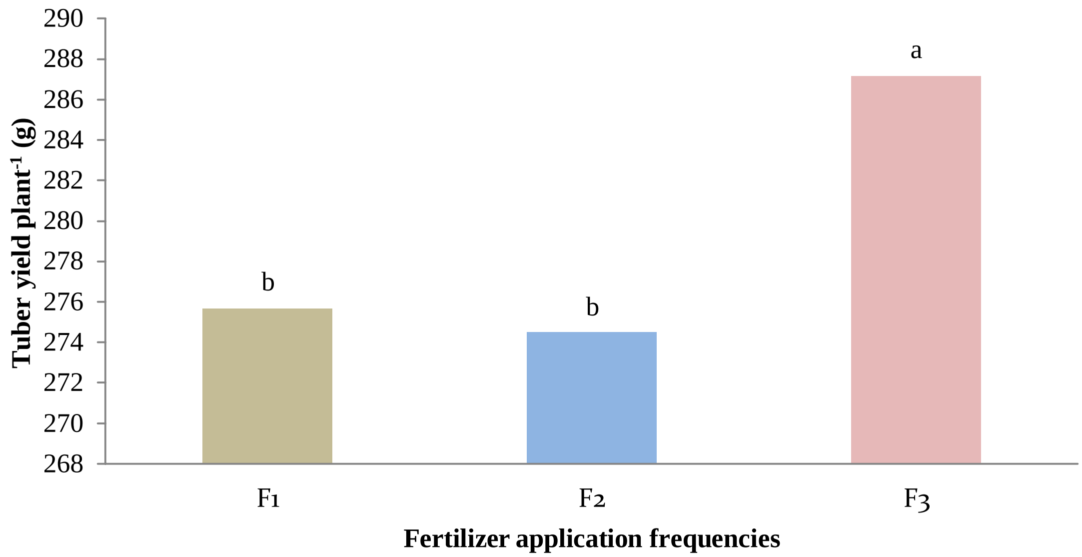
Combined effect of different fertilizer and irrigation frequency

The combined effect of different fertilizer and irrigation frequency had significant effect on number of tuber plant^{-1} of potato (Table 1). Experimental result showed that the highest number of tuber plant^{-1} of potato (6.54) was observed in F_3I_2 treatment combination. Whereas the lowest number of tuber plant^{-1} of potato (5.03) was observed in F_1I_1 treatment combination.

4.2 Tuber yield plant^{-1}

Effect of fertilizer application frequency

Tuber yield plant^{-1} of potato was significantly influenced by various fertilizer application frequency (Figure 3). The highest tuber yield plant^{-1} of potato (287.16 g) was observed in the F_3 treatment. While the F_2 treatment had the lowest tuber yield plant^{-1} of potato (274.50) which was statistically similar with F_1 (275.67 g) treatment. The differences of tuber yield plant^{-1} of potato may be explained by the fact that fertilizer efficiency had an impact on how proteins and carbohydrates were metabolized. This effect was directly related to the processes of sugar conversion and also has an impact on photosynthesis, which is crucial for producing the carbohydrates and proteins required for the growth of vegetative parts as well as the development of reproductive parts. Ayyub *et al.* (2018) reported that the overall, qualitative characters of tubers and yield enhanced with split fertilizer application as compared to all fertilizer applied once at planting time whereas, there was no significant difference between tuber nitrogen, potassium, phosphorus and protein contents.

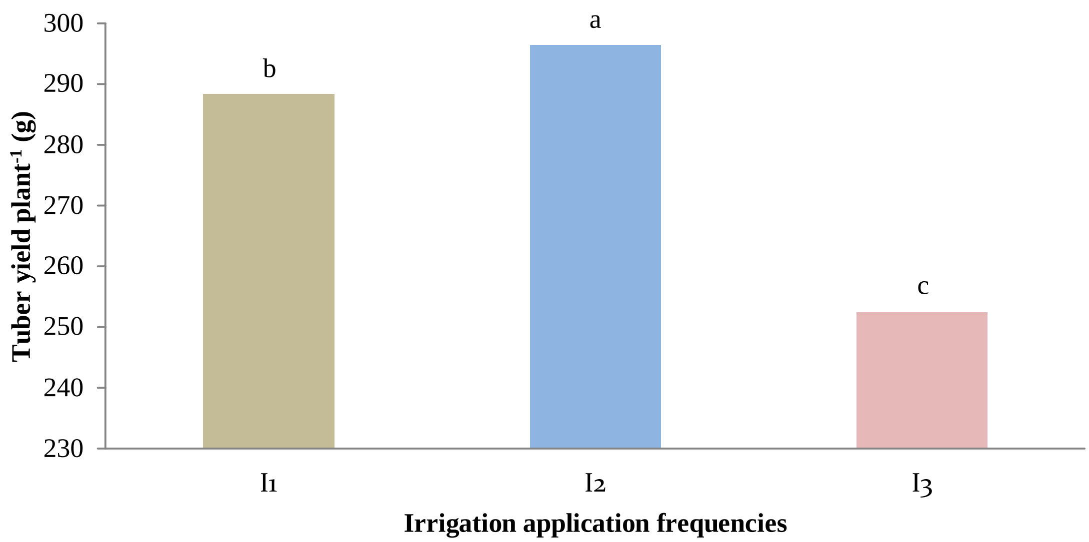


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018]

Figure 3. Effect of different fertilizer application frequency on tuber yield plant^{-1} of potato

Effect of irrigation frequency

The results of the experiment showed that the tuber production of potato plant^{-1} varied significantly depending on the frequency of irrigation (Figure 4). The results of the experiment showed that the potato plant^{-1} with the maximum tuber yield (296.47 g) was found in the I_2 treatment. Whereas the I_3 treatment had the lowest tuber yield plant^{-1} of potato (252.50g). The frequency of irrigation established a nearly constant water regime in the root zone and ensured that plants grew under proper soil water conditions for optimum production of the plant's dry biomass, which ultimately influences proper plant growth and development result in increased tuber yield plant^{-1} of potato. The result was similar with the findings of Amer *et al.* (2016) who found that total tubers yield was significantly increased with increasing water supply.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 4. Effect of different irrigation application frequency on tuber yield plant^{-1} of potato

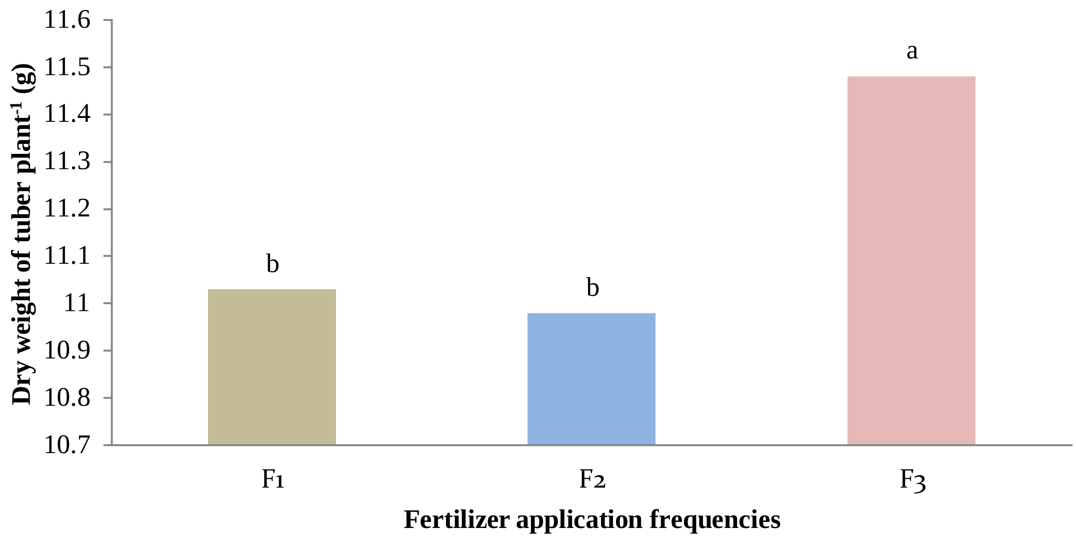
Combined effect of different fertilizer and irrigation frequency

The combined effect of different fertilizer and irrigation frequency had significant effect on tuber yield plant^{-1} of potato (Table 1). Experimental result showed that the highest tuber yield plant^{-1} of potato (308.90 g) was observed in F_3I_2 treatment combination. Whereas the lowest tuber yield plant^{-1} of potato (243.40 g) was obtained by in F_1I_3 treatmentcombination which was statistically similar with F_1I_3 treatment combination F_2I_3 (255.10 g) treatment combination.

4.3 Dry weight of tuber plant^{-1}

Effect of fertilizer application frequency

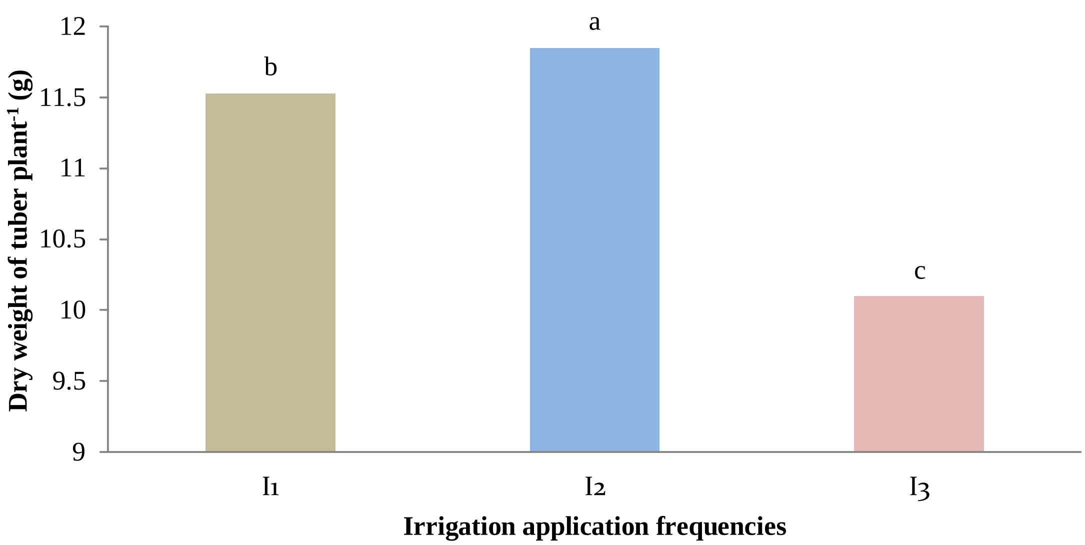
The experimental findings demonstrated that different fertilizer application frequency had shown significant effect on dry weight of tuber plant^{-1} of potato (Figure 5). Experimental result revealed that the F_3 treatment had the highest dry weight of tuber plant^{-1} of potato (11.48 g). While F_2 treatment showed the lowest dry weight of tuber plant^{-1} of potato (10.98 g) which was statistically similar with F_1 (11.03 g) treatment. This might be due to an increase in cell elongation and more vegetative growth attributed to crop requirements of the additional fertilizer nutrients (*i.e.* NPK) for its normal physiological growth. Banjare *et al.* (2014) reported that the increase in potato yield attributing parameters like number of stolon, fresh and dry weight of tuber per plant and tuber yield ha^{-1} increased with increased fertilizer application rate and the fertilizer split application method.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018]

Figure 5. Effect of different fertilizer application frequency on dry weight of tuber plant^{-1} potato Effect of irrigation frequency

The frequency of irrigations caused a significant fluctuation in the dry weight of tuber plant^{-1} of potato (Figure 6). Experiment result revealed that the highest dry weight of tuber plant^{-1} of potato (11.85 g) was observed in I_2 treatment. Whereas the lowest dry weight of tuber plant^{-1} of potato (10.10 g) was observed in I_3 treatment. The best irrigation interval would supply the crop with enough moisture in the top layer, where the majority of the potato roots are located, leading to greater crop nutrient uptake and ultimately higher output. However, constant irrigation can drown any plant if it receives too much water. When more water is supplied than the crop needs or the soil can absorb, root respiration lacks oxygen. This can have a detrimental effect on productivity and quality, slow down plant development, and increase the likelihood of rot result in lowest dry weight of tuber plant^{-1} of potato. The result obtained from the present study was similar with the findings of Masoudi (2010) who reported that tuber dry weight of potato varied with different irrigation intervals.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 6. Effect of different irrigation application frequency on dry weight of tuber plant^{-1} potato

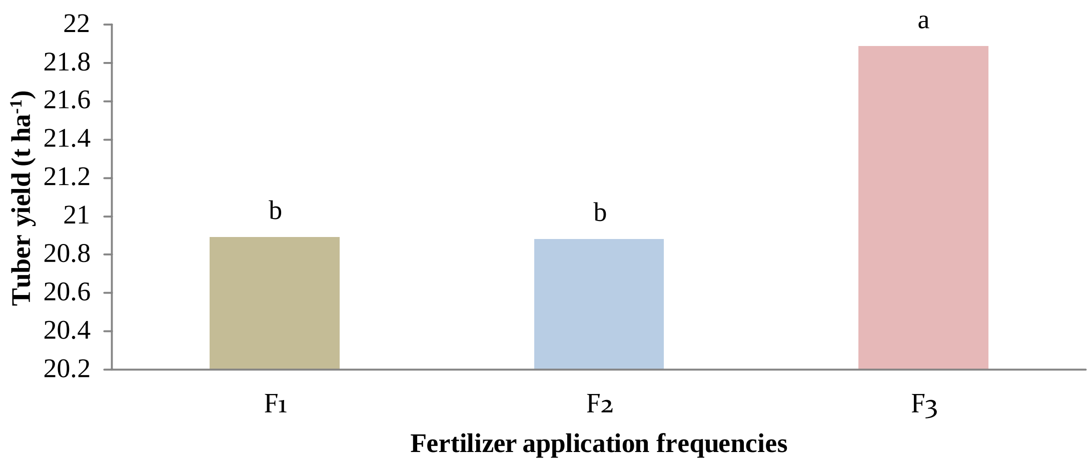
Combined effect of different fertilizer and irrigation frequency

The dry weight of tuber plant^{-1} of potato had been significantly influenced by the combined effects of various fertilizer and irrigation application frequencies (Table 1). The F_3I_2 treatment combination rerecorded the highest dry weight of tuber plant^{-1} of potato (12.36 g). While the F_1I_3 treatment combination had the lowest dry weight of tuber plant^{-1} of potato (9.74 g) which was statistically similar with F_2I_3 (10.20 g) treatment combination.

4.4 Tuber yield

Effect of fertilizer application frequency

The frequency of fertilizer application had significant effect on potato tuber yield (Figure 7). The F_3 treatment had the highest potato tuber yield (21.89 t ha^{-1}). While the F_2 treatment had the lowest potato tuber yield (20.88 t ha^{-1}), and it was statistically comparable to the F_1 (20.89 t ha^{-1}) treatment. Mugo *et al.* (2020) reported that the low yields of potato could be attributed to soil infertility and improper use of fertilizer. Verma (2020) reported that the growth, yield attributing characters and yield was influenced by split application of nitrogen and significantly increased values were obtained. Among seven treatments, 50 % basal N of RDF + 25 % top dressing at 25 DAP + two foliar spray @ 2 % urea at 40 and 55 DAP was found best regarding growth, tuber yield and B-C ratio.

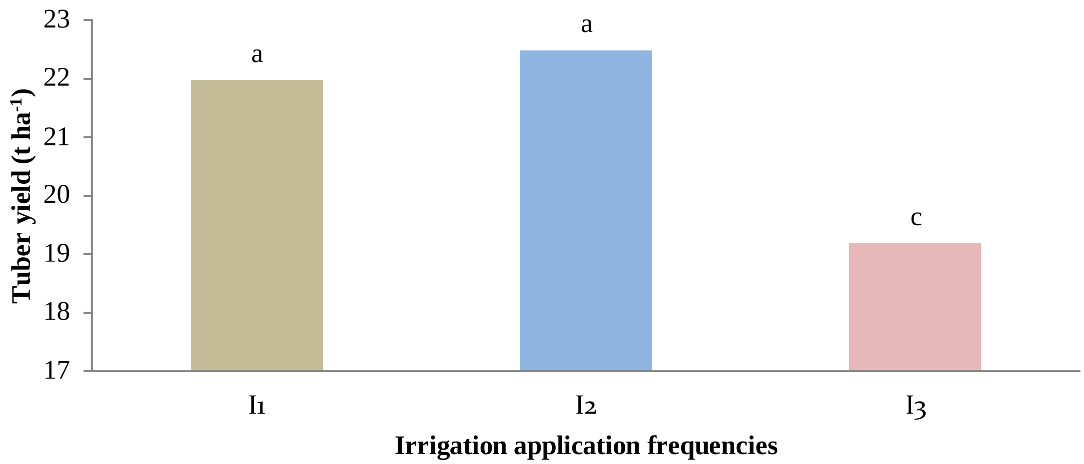


In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018]

Figure 7. Effect of different fertilizer application frequency on tuber yield of potato

Effect of irrigation frequency

The experiment results revealed that the potato tuber yield varied significantly depending on the frequency of irrigation (Figure 8). According to the results of the experiment, the potato with the highest tuber yield (22.48 t ha^{-1}) was found in the I_2 treatment which was statistically similar with I_1 (21.98 t ha^{-1}) treatment. However the I_3 treatment had the lowest potato tuber yield (19.20 t ha^{-1}). Djaman *et al*. (2021) mentioned that the quality and productivity of the potato tubers can be influenced by irrigation management. Patel and Rajput (2007) reported that water deficiency caused a reduction of yield by reducing growth of crop canopy and biomass that may be due to low tolerance of potato for water stress.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 8. Effect of different irrigation application frequency on tuber yield of potato

Combined effect of different fertilizer and irrigation frequency

On the potato tuber yield, the combined effects of various fertilizers and irrigation frequency were quite significant (Table 1). The results of the experiment demonstrated that the F_3I_2 treatment combination produced the highest tuber yield of potatoes (23.50 t ha^{-1}) which was statistically equivalent to the F_1I_3 (22.48 t ha^{-1}) treatment combination. However the F_1I_3 treatment combination, had the lowest tuber yield of potatoes (18.50 t ha^{-1}) which was statistically equivalent to the F_2I_3 (19.40 t ha^{-1}) and F_3I_3 (19.70 t ha^{-1}) treatment combination.

Table 1. Combined effect of different fertilizer and irrigation frequencies application on, number of tuber plant^{-1}, tuber yield plant^{-1}, dry weight of tuber plant^{-1} and tuber yield of potato

Treatment combinations	Number of tubers plant^{-1}	Tuber yield plant^{-1} (g)	Dry weight of tuber plant^{-1} (g)	Tuber yield t ha^{-1}
F_1I_1	5.03 g	289.60 b	11.58 b	22.03 b
F_1I_2	6.27 b	294.00 b	11.76 b	22.16 b
F_1I_3	5.47 f	243.40 d	9.74 d	18.50 c
F_2I_1	5.90 cd	281.90 b	11.28 b	21.44 b
F_2I_2	6.05 bc	286.50 b	11.46 b	21.79 b
F_2I_3	5.53 ef	255.10 cd	10.20 cd	19.40 c
F_3I_1	5.73 de	293.57 b	11.74 b	22.48 ab
F_3I_2	6.54 a	308.90 a	12.36 a	23.50 a
F_3I_3	5.30 f	259.00 c	10.36 c	19.70 c
$LSD_{(0.05)}$	0.24	13.11	0.52	1.28
CV(%)	2.80	2.39	2.39	3.54

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP), F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018] I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

4.5 Dry matter content tuber^{-1}

Effect of fertilizer application frequency

Different fertilizer application frequency significantly influenced dry matter content tuber^{-1} of potato (Figure 9). Experimental result showed that the highest dry matter content tuber^{-1} of potato (20.27 %) was found in F_3 treatment. While the F_2 treatment had the lowest dry matter content tuber^{-1} of potato (18.53 %) which was statistically similar with F_1 (18.57 %) treatment. Priyanka *et al*. (2020) reported that different fertilizer managements significantly influenced dry matter content of potato tuber and the highest dry matter content (19.85%), was recorded with the T_6 (6 (50% basal N + 25% top dressing at 25 DAP + two foliar spray @ 2% urea at 40 & 55 DAP) treatment. Wani *et al*. (2014) reported that plant height and dry matter accumulation was higher with the split application of potassium as compared to single basal application.

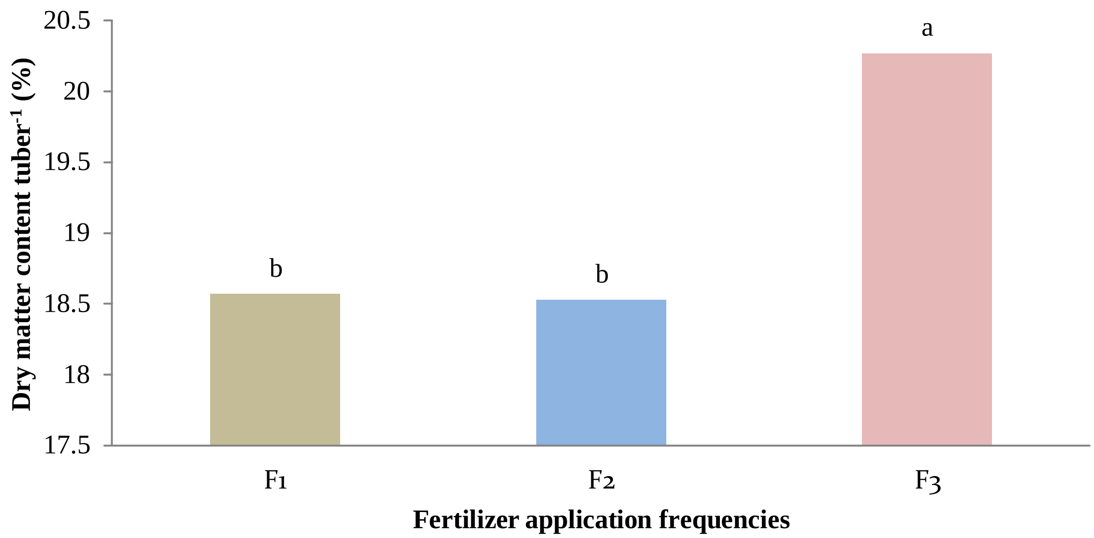


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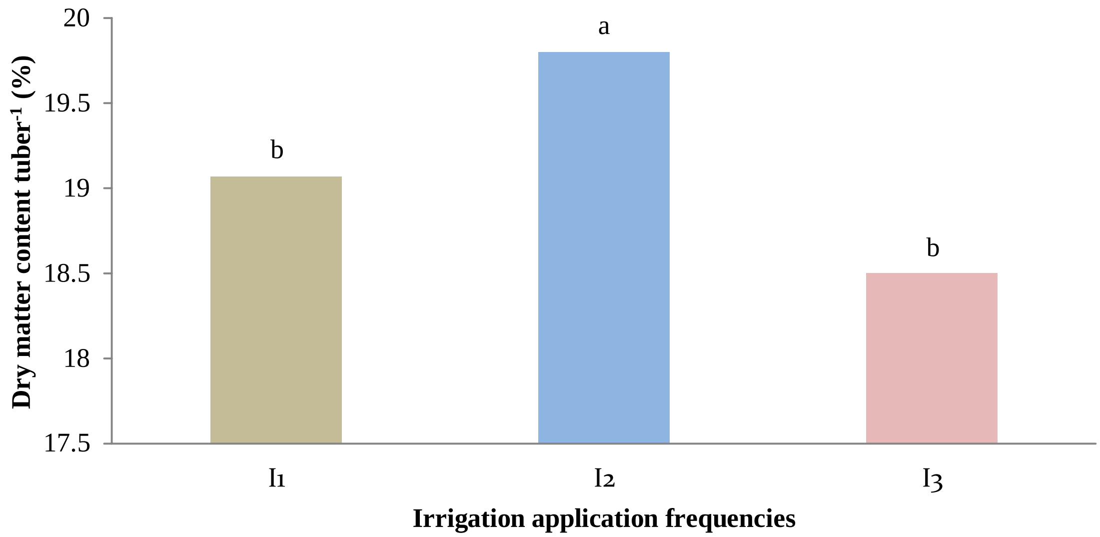
Figure 9. Effect of different fertilizer application frequency on dry matter content tuber^{-1} of potato

Effect of irrigation frequency

The findings of the experiment showed that the frequency of irrigation had shown significant effect on the dry matter content tuber^{-1} of potato (Figure 10). According to the results of the experiment, the highest dry matter content tuber^{-1} of potato (19.80 %) was found in the I_2 treatment. However the I_3 treatment had the lowest dry matter content tuber^{-1} of potato (18.50 %) which was statistically similar with I_1 (19.07 %) treatment. Abubaker *et al*. (2014) reported an increase in specific gravity with an increase in irrigation frequency. Early appropriate stages irrigation increases tuber dry matter and continuous or late-season irrigation can reduce potato dry matter content.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 10. Effect of different irrigation application frequency on dry matter content tuber^{-1} of potato

Combined effect of different fertilizer and irrigation frequency

The effects of various fertilizers in combination with the frequency of irrigation had shown significant effect on the dry matter content tuber^{-1} of potato (Table 2). The results of the experiment demonstrated that the F_3I_2 treatment combination produced the highest dry matter content tuber^{-1} of potato (20.80 %) which was statistically equivalent to the F_3I_1 (20.60 %) and F_3I_1 (20.10 %) treatment combination. However the F_3I_1 treatment combination, had the lowest dry matter content tuber^{-1} of potato (20.60 %) which was statistically equivalent to the F_1I_1 (18.10 %) treatment combination.

4.6 Specific gravity (g cm^{-3})

Effect of fertilizer application frequency

The specific gravity of potato was significantly influenced by different fertilizer treatment frequencies (Figure 11). The results of the experiment indicated that the F_3 treatment had the highest specific gravity of potato (1.084 g cm^{-3}). Whereas the lowest specific gravity of potato was found in the F_2 treatment (1.078 g cm^{-3}) treatment. Bista and Bhandari, (2019) reported that many factors such as potato variety, location, growing temperature, etc. are responsible for specific gravity of potato. However, K fertilization plays greater role in determining the specific gravity of potato tuber. Tubers fertilized with potassium sulfate (low salt index and less than 1% chloride) had higher specific gravities than those fertilized with potassium chloride (high salt index and high 47% chloride). El-Hadidi *et al.* (2017) reported that the quality parameters of potato like dry matter, specific gravity, total carbohydrate, reducing sugar and starch contents were improved with both nitrogen and K application.

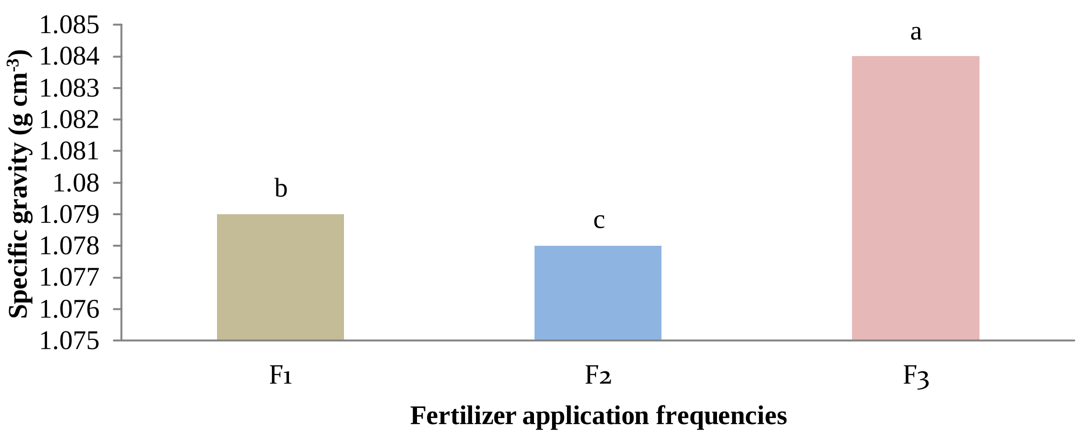


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Figure 11. Effect of different fertilizer application frequency on specific gravity of potato

Effect of irrigation frequency

The experiment's findings demonstrated that the frequency of irrigation had shown non significant effect on the specific gravity of potato (Figure 12). According to the experiment's findings, the I_2 treatment had the highest specific gravity of potato (1.083 g cm^{-3}). The I_1 treatment, however, had the lowest potato specific gravity (1.079 g cm^{-3}).

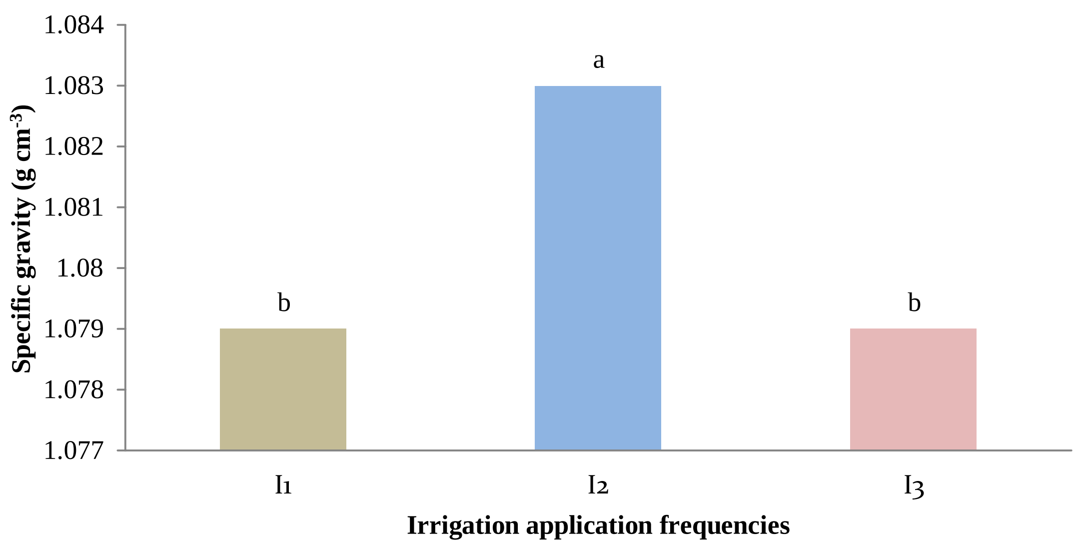

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Figure 12. Effect of different irrigation application frequency on specific gravity of potato

Combined effect of different fertilizer and irrigation frequency

The specific gravity of potato was shown non significant effect on the use of different fertilizers in conjunction with the frequencies of irrigation (Table 3). The experiment's findings showed that the F_3I_2 treatment combination produced the highest specific gravity of potato (1.087 g cm^{-3}). The lowest specific gravity of potato was found in the F_2I_3 treatment combination (1.074 g cm^{-3}).

4.7 Starch content (%)

Effect of fertilizer application frequency

The starch content of potato was significantly influenced by different fertilizer treatment frequencies (Figure 13). The results of the experiment indicated that the F_3 treatment had potatoes with the highest starch content (13.90 %). The lowest starch content of potato was found in the F_1 treatment (11.60%), which was statistically comparable to the F_2 treatment (12.00%). Khan *et al.* (2010) also reported that starch content of tuber was increased with the increasing levels and split application of potash as compared to that of control or basal application only. It might be due to the better vegetative growth and role of potassium in starch formation and its translocation to tubers which resulted in more reserve food accumulation in tubers.

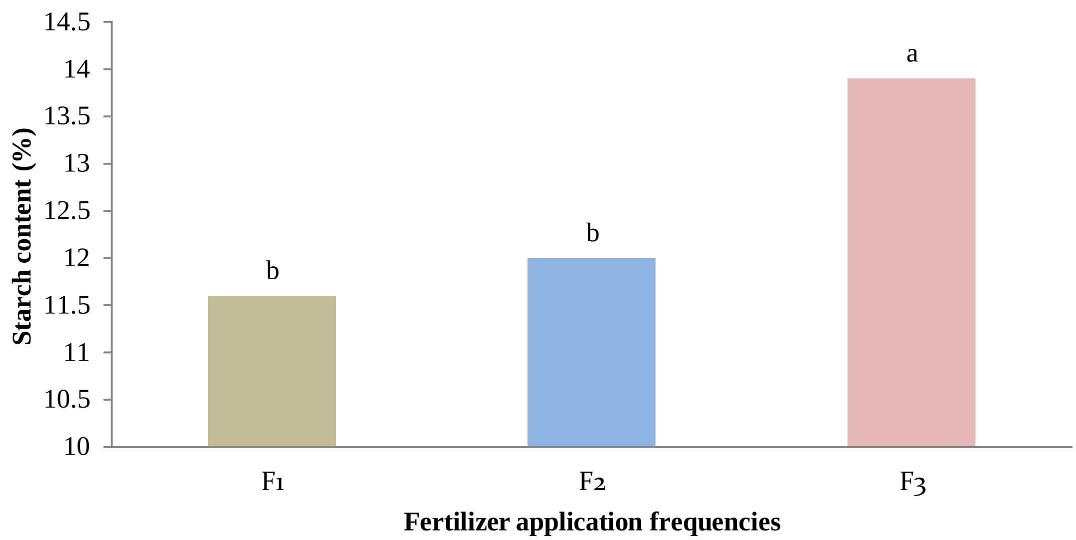

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Figure 13. Effect of different fertilizer application frequency on starch content tuber^{-1} of potato

Effect of irrigation frequency

The results of the experiment revealed that the frequency of irrigation had a significant effect on the starch content of potato (Figure 14). The I_2 treatment had the highest starch content of potato (13.27%), according to the results of the experiment. However, the I_1 treatment had the lowest starch content of potato (12.07%), which was statistically similar to the I_3 (12.17%) treatment. The transfer of photosynthate into the potato tuber eventually increased the starch content of the potato because optimal irrigation levels produced the ideal soil moisture for growth. The findings were consistent with those of Djaman *et al*. (2021), who discovered that irrigation management can affect the quality of production and the chemical composition of tubers during storage.

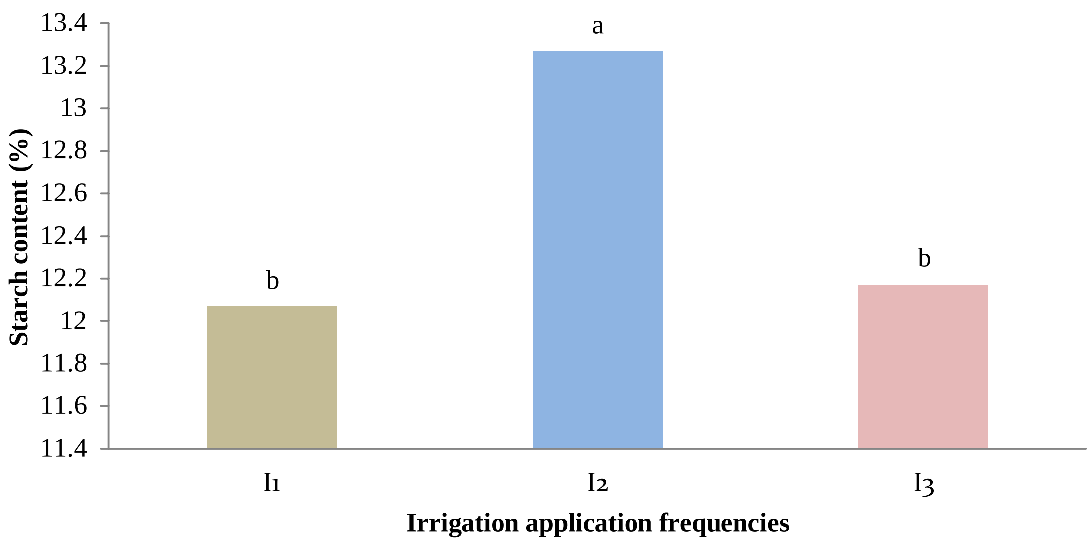

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Figure 14. Effect of different irrigation application frequency on starch content tuber^{-1} of potato

Combined effect of different fertilizer and irrigation frequency

The starch content of potatoes was significantly affected by the use of different fertilizers in conjunction with the frequencies of irrigation (Table 2). The experiment's findings showed that the F_3I_2 treatment combination produced potato with the highest starch content (14.8%). The lowest amount of potato starch was found in the F_2I_3 treatment combination (11.10%), which was statistically equal to the F_2I_1 (11.50%), F_1I_3 (11.90%), F_1I_2 (11.60%), and F_2I_1 (11.30%) treatment combinations.

Table 2. Combined effect of different fertilizer application and irrigation frequency on dry matter, specific gravity and starch content tuber^{-1} of potato

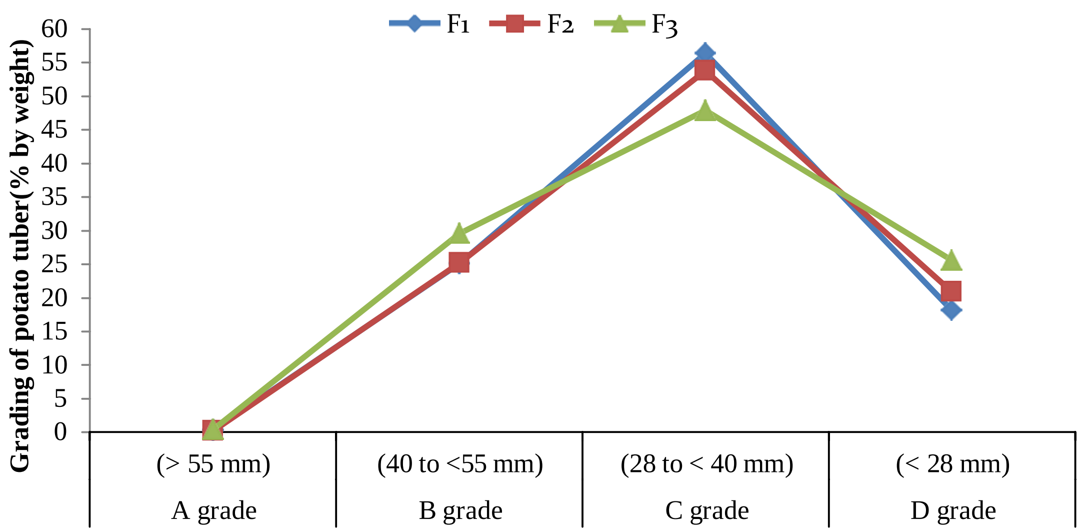
Treatment combinations	Dry matter content tuber^{-1} (%)	Specific gravity (g cm^{-3})	Starch (%)
F_1I_1	18.10 cd	1.077	11.30 c
F_1I_2	18.50 c	1.079	11.60 c
F_1I_3	19.10 bc	1.082	11.90 c
F_2I_1	18.50 c	1.077	11.50 c
F_2I_2	20.10 ab	1.082	13.40 b
F_2I_3	17.00 d	1.074	11.10 c
F_3I_1	20.60 a	1.084	13.40 b
F_3I_2	20.80 a	1.087	14.80 a
F_3I_3	19.40 bc	1.081	13.50 b
$LSD_{(0.05)}$	1.40	Ns	0.63
CV(%)	3.02	1.07	2.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP), F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP), [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018] I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

4.8 Grading of potato tuber

Effect of fertilizer application frequency

Different fertilizer application frequency significantly influenced grading of potato tuber (Figure 15). Experimental result revealed that the F_3 treatment had the highest A (0.40 %), B (29.56 %) and D (25.60 %) grade of potato. However F_1 treatment had the highest C (56.40 %) grade of potato. While the lowest A grade (0.18 %) was found in F_2 treatment, B grade (25.08 %) in F_1 treatment which was statistically similar with F_2 treatment (25.24 %), C grade (25.08 %) in F_3 treatment and finally the D grade (18.14 %) was found in F_1 treatment. The result obtained from the present study was similar with the findings of Patel *et al.* (2011) who reported that F_3 (100% recommended dose of N and K) treated plot recorded significantly higher number and yield of processing grade A and B tubers of potatoes, but it was at par with F_2 (75% recommended dose of N and K) treatment.

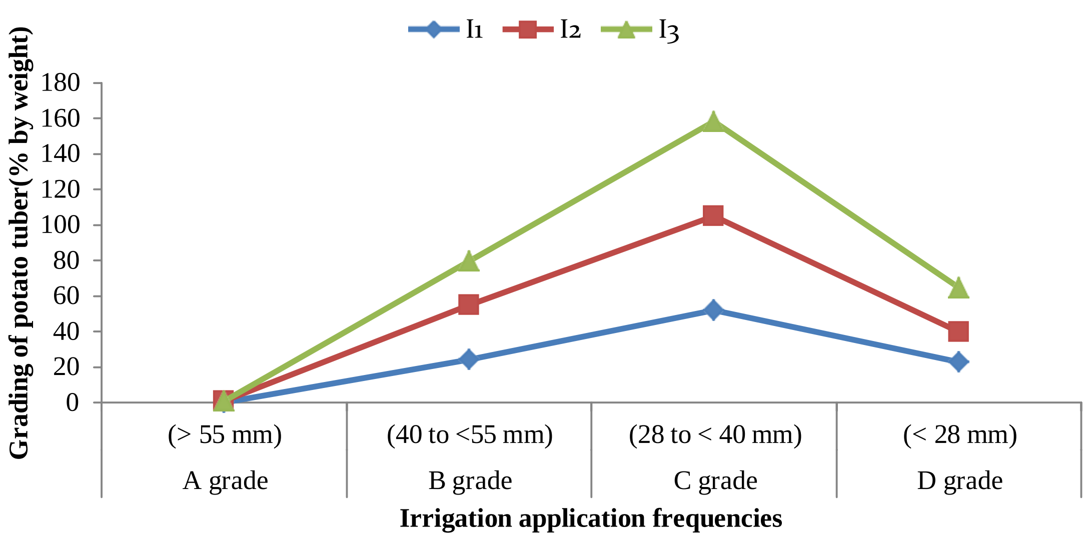


Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP)

Figure 15. Effect of fertilizer application frequency on grading of potato tuber

Effect of irrigation frequency

Irrigation frequency had a significant impact on potato grading based on diameter (Figure 14). Experimental result showed that the highest grade potato A (0.53 %) and B (30.84 %) was found in I_2 treatment. However the highest grade potato C (53.21 %) and D (25.09 %) was found in I_3 treatment. While the I_1 treatment had the lowest A (0.19 %), B (24.12 %) and C (52.02 %) grade of potato which was statistically similar with I_3 treatment for A (0.20 %) and B (24.93 %). However the lowest D (16.92 %) grade of potato was found in I_2 treatment.Irfan *et al*. (2015) reported that yield attributes viz. total number, weight (grade wise), total weight of tubers hill^{-1}, plot^{-1} and ha^{-1} was highest under 1.0 IW/ CPE ratio over 0.8 IW/CPE ratio. Mahima and Mrinal (2013) concluded that, irrigation applied at 25 mm CPE recorded significantly the highest yield of both B grade (25-50 g) and C grade (50- 75 g) tubers. Both B and C grades has higher market price and mostly preferred by people than A grade and D grade size tubers. Likewise, application of mulch significantly24.04% higher yield over non mulch condition.



In the bar graphs means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability). Here I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

Figure 16. Effect of irrigation application frequency on grading of potato tuber

Combined effect of different fertilizer and irrigation frequency

The combined effect of various fertilizers and irrigation frequency had a significant effect on potato diameter grading (Table 3). The F_3I_2 treatment combination had the highest A (0.72 %) and B (32.13 %) grade of potato which was statistically similar with F_1I_2 treatment combination for B (31.71 %) grade of potato. The highest C grade (59.73 %) of potato was found in F_1I_1 treatment combination. The F_3I_3 treatment combination had the highest D grade (28.90 %) of potato. However the lowest A (0.10 %) and B (20.83 %) grade of potato was found in F_1I_3 treatment combinations which was statistically similar to the F_2I_1 treatment combinations for both A (0.10 %) and B (21.03 %) grade of potato, However the F_3I_1 treatment combination had the lowest C (42.07 %) grade of potato and the lowest D (12.54 %) grade of potato was found in F_1I_2 treatment combinations.

Table 3. Combined effect of different fertilizer application and irrigation frequency on grading(% by weight) of potato tuber

Treatment combinations	A grade (> 55 mm)	B grade 40 to <55 mm	C grade 28 to < 40 mm	D grade (< 28 mm
F_1I_1	0.37 c	22.70 d	59.73 a	17.10 d
F_1I_2	0.54 b	31.71 a	55.19 b	12.54 e
F_1I_3	0.10 f	20.83 d	54.27 b	24.77 b
F_2I_1	0.10 f	21.03 d	54.26 b	25.06 b
F_2I_2	0.32 d	28.67 b	55.04 b	16.01 d
F_2I_3	0.13 e	26.03 c	52.17 b	21.60 c
F_3I_1	0.10 f	28.62 b	42.07 d	25.70 b
F_3I_2	0.72 a	32.13 a	48.46 c	22.20 c
F_3I_3	0.37 c	27.93 bc	53.20 b	28.90 a
$LSD_{(0.05)}$	0.02	2.57	3.20	1.61
CV(%)	4.76	5.01	3.41	4.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF +

20% N and K each at 30, 45 and 60 DAP), F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018], I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP)

CHAPTER V

SUMMERY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from September-2020 to February-2021, to study the yield and quality of potato (*Solanum tuberosum L.*) as influenced by fertilizer and irrigation frequency. The experiment consisted of two factors, and followed split plot design with three replications. Factor A. Different fertilizer application frequency (3) *viz:* F_1= Split 2 times N and K (50 % basal N and K of RDF + 25% N and K each at 30 and 45 DAP), F_2= Split 3 times N and K (40 % basal N and K of RDF + 20% N and K each at 30, 45 and 60 DAP) and F_3= Split 3 times N and K and 2 times P (40 % basal N, K and P of RDF + 20% N and K each at 30, 45 and 60 DAP +60 % P at 30 DAP) [Application of recommendation dose of fertilizers according to Fertilizer Recommendation Guide (FRG),2018]) were placed in the main-plot and Factor B. Different irrigation frequency (3) *viz:* I_1= Three irrigation (20, 30 and 60 DAP), I_2= Four irrigation (20, 30, 45 and 60 DAP) and I_3= Five irrigation (20, 30, 45, 60 and 75 DAP) were placed in the sub-plot. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated. These data revealed significant variance in potato yield, and quality characteristics as a result of fertilizer application frequencies, irrigation frequencies and combination of these factors.

In case of different fertilizer application frequencies, F_3 treatment had the highest number of tuber plant^{-1} (5.86), tuber yield plant^{-1} (287.16 g), dry weight of tuber plant^{-1} (11.48 g), tuber yield (21.89 t ha^{-1}), specific gravity (1.084 g cm^{-3}) starch content (13.90 %), and the highest yield of A (0.40 %), B (29.56 %) and D (25.60 %) graded of potato. However the lowest tuber yield plant^{-1} of potato (274.50), dry weight of tuber plant^{-1} (10.98 g), potato tuber yield (20.88 t ha^{-1}), dry matter content tuber^{-1} of potato (18.53 %), specific gravity of potato (1.078 g cm^{-3}) and the lowest A grade (0.18 %) were found in F_2 treatment. While the lowest B grade (25.08 %) was found in F_1 treatment C grade (25.08 %) in F_3 treatment and finally the D grade (18.14 %) was found in F_1 treatment.

In terms of different irrigation frequencies, the highest number of tuber plant^{-1} (6.29), tuber yield plant^{-1} (296.47 g), dry weight of tuber plant^{-1} (11.85 g), tuber yield (22.48 t ha^{-}

^{1}), starch content (13.90 %), dry matter content tuber^{-1} (19.80 %), starch content (13.27 %) and yielded the highest graded of A (0.53 %) and B (30.84 %) type of potato were found in I_2 treatment. However the highest C (53.21 %) and D (25.09 %) was found in I_3 treatment. While the I_3 treatment had the lowest number of tuber plant^{-1} (5.43), tuber yield plant^{-1} (252.50 g), dry weight of tuber plant^{-1} (10.10 g), tuber yield (19.20 t ha^{-1}), dry matter content tuber^{-1} (18.50 %).

In case of combination, the F_3I_2 treatment combination demonstrated the best result and recorded the highest number of tuber plant^{-1} (6.54), tuber yield plant^{-1} (308.90 g), dry weight of tuber plant^{-1} (12.36 g), tuber yield (23.50 t ha^{-1}), starch content (13.90 %), dry matter content tuber^{-1} (20.80 %), starch content (14.80 %) and yielded the highest A (0.72 %) and B (32.13 %) graded of potatoes. However the lowest number of tuber plant^{-1} of potato (5.03) was in F_1I_1 treatment combination. The lowest tuber yield plant^{-1} of potato (243.40 g), dry weight of tuber plant^{-1} of potato (9.74 g), tuber yield of potatoes (18.50 t ha^{-1}) and the lowest A (0.10 %) and B (20.83 %) grade of potato were found in F_1I_3 treatment combinations. However the F_3I_1 treatment combination had the lowest dry matter content tuber^{-1} of potato (20.60 %) and C (42.07 %) grade of potato and the lowest D (12.54 %) grade of potato was found in F_1I_2 treatment combinations.

Conclusion

Based on the above findings, our experimental results revealed that, fertilizer application frequencies, irrigation frequencies and combination of these factors significantly influenced the yield and quality characteristics of potato.

i. Among different treatment of fertilizer application frequency The F_3 treatment showed the most tuber plant^{-1} (5.86), tuber yield plant^{-1} (287.16 g), dry weight of tuber plant^{-1} (11.48 g), tuber yield (21.89 t ha^{-1}), specific gravity (1.084 g cm^{-3}) starch content (13.90 %) as well as the highest yield of potato grades A (0.40 %), B (29.56 %)
ii. Regarding various irrigation frequencies, the highest tuber plant^{-1} number (6.29), highest tuber yield plant^{-1} (296.47 g), dry weight of tuber plant^{-1} (11.85 g), tuber yield (22.48 t ha^{-1}), starch content (13.90 %), dry matter content of tuber^{-}

(19.80%) and graded A (0.53 %) and B (30.84 %) type of potato yield were all found in the I_2 treatment.

iii. In terms of combination, the F_3I_2 treatment combination showed the best results, recording the highest number of tuber plant^{-1} (6.54), tuber yield plant^{-1} (308.90 g), dry weight of tuber plant^{-1} (12.36 g), tuber yield (23.50 t ha^{-1}), starch content (13.90 %), dry matter content tuber^{-1} (20.80%), starch content (14.80 %) and yielding the highest A (0.72 %) and B (32.13 %) graded of potatoes.

Therefore, it was indicated that cultivation of potato through application of recommendation dose of fertilizer through split 3 times: N, K and 2 times P (F_3) combined with four irrigation (20,30, 45 and 60 DAP) (I_2) would help to enhanced yield and qualities of potatoes.

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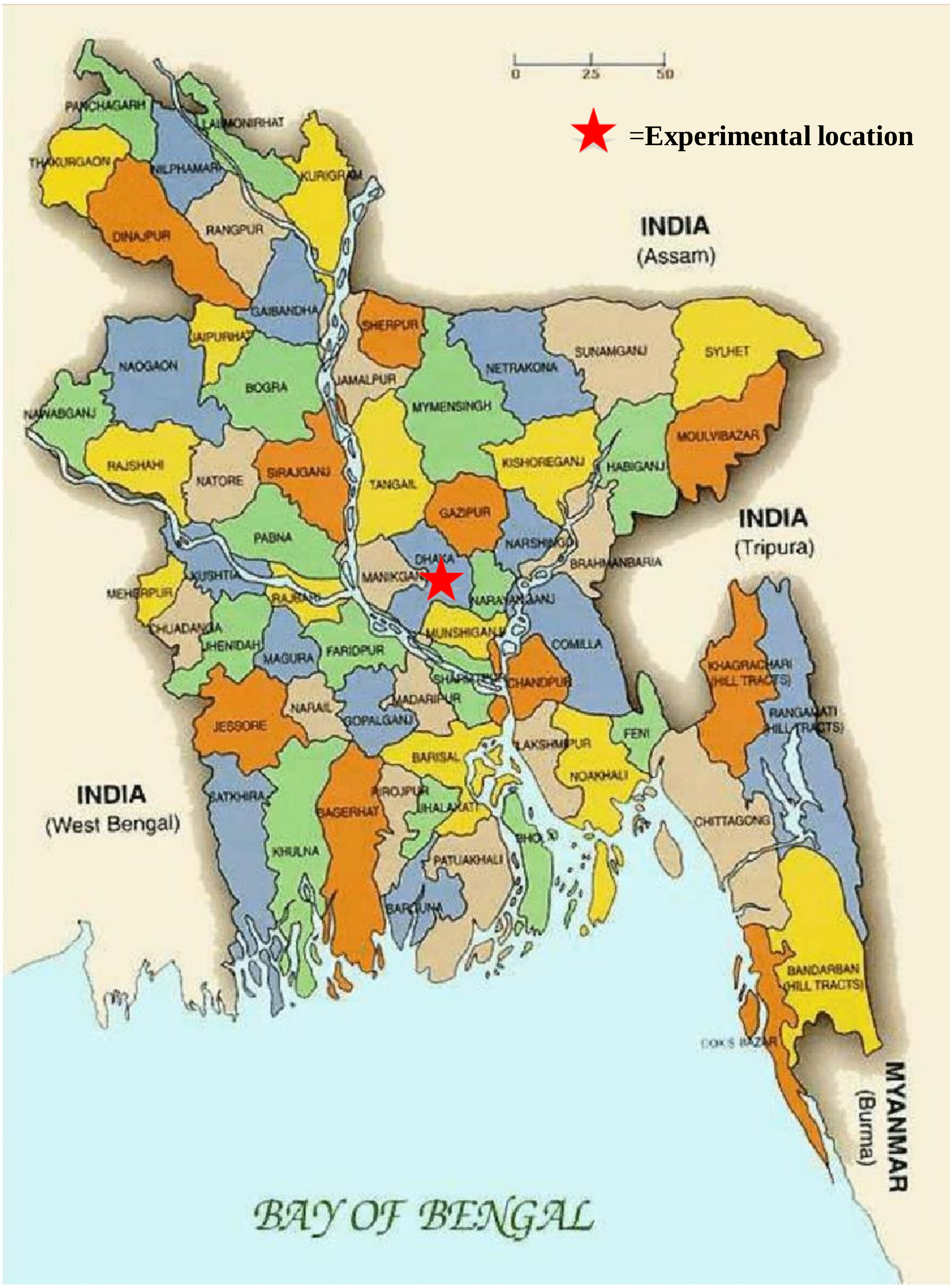
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from September 2020 to February, 2021.

Year	**Month**	**Air temperature (^0C)**		**Relative humidity (%)**	**Average rainfall (mm)**
		Maximum	**Minimum**		
2020	September	32.4°C	25.7°C	80%.	86 mm
	October	31.2°C	23.9°C	76%.	52 mm
	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2021	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data of number of tuber plant^{-1}, tuber yield plant^{-1}, dry weight of tuber plant^{-1} and tuber yield of potato

Source	**DF**	Mean square of			
		Number of tuber plant^{-1}	Tuber yield plant^{-1}	Dry weight of tuber plant^{-1}	Tuber yield t ha^{-1}
Replication (R)	2	0.10037	40.15	0.06424	0.2704
Fertilize (F)	2	0.19273*	440.28*	0.70445*	3.0410*
Error	4	0.00370	46.81	0.07490	0.2704
Irrigation (I)	2	1.91729*	4926.72*	7.88275*	28.1658*
F×W	4	0.33478*	126.51*	0.20242*	0.6867*
Error	12	0.02593	44.59	0.07135	0.5637

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of on dry matter, specific gravity and starch content tuber^{-1} of potato

Source	**DF**	Mean square of		
		Dry matter content tuber^{-1} (%)	Specific gravity	Starch (%)
Replication (R)	2	0.75111	4.444E-07	0.6400
Fertilize (F)	2	8.84333*	9.700E-05*	13.5900*
Error	4	0.75111	4.444E-07	0.3733
Irrigation (I)	2	3.82333*	3.700E-05 Ns	3.9900*
F×W	4	2.93333*	2.900E-05 Ns	1.3200*
Error	12	0.33444	1.338E-04	0.1289

Ns: Non significant
*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on grading of potato tuber

Source	**DF**	Mean square of			
		A grade (> 55 mm)	B grade 40 to <55 mm	C grade 28 to < 40 mm	D grade (< 28 mm
Replication (R)	2	0.00001	1.868	5.444	1.778
Fertilize (F)	2	0.10893*	58.096*	170.420*	128.199*
Error	4	0.00001	1.734	2.111	0.444
Irrigation (I)	2	0.33023*	121.063*	3.439 Ns	158.148*
F×W	4	0.07503*	20.425*	61.195*	26.350*
Error	12	0.00021	1.779	3.222	0.889

Ns: Non significant
*: Significant at 0.05 level of probability