EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH AND SEED YIELD OF GIMAKALMI

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JUNE, 2022

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A Thesis

Submitted to the Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

SEED TECHNOLOGY

SEMESTER: JANUARY- JUNE, 2022

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH AND SEED YIELD OF GIMAKALMI"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **MD. SADDAM HOSSAIN**, Registration No. **15-06666** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2022
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To

My Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, Dr. Tahmina Mostarin, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for her continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, Dr. Khaleda Khatun, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for her scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.

The author feels to express his heartfelt thanks to the honorable Director, Professor Dr. Md. Ismail Hossain, along with all other teachers and staff members of the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.

The author feels proud to express his deepest and endless gratitude to all of his course mates and friends to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses his heartfelt thanks to his beloved parents, elder sister and brother and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

EFFECT OF NITROGEN AND PHOSPHORUS ON GROWTH AND SEED YIELD OF GIMAKALMI

ABSTRACT

An experiment was conducted at the farm of Sher-e-Bangla Agricultural University, during the period of September 2021 – March, 2022 to study the effect of nitrogen and phosphorus on growth and seed yield of gimakalmi. Two factors *viz*., Factor A: 4 nitrogen levels; N_0 (control), N_1 (60 kg N ha^{-1}), N_2 (90 kg N ha^{-1}) and N_3 (120 kg N ha^{-1}) and Factor B: 4 phosphorus levels *viz*., P_0 (control), P_1 (20 kg P ha^{-1}), P_2 (30 kg P ha^{-1}) and P_3 (40 kg P ha^{-1}) were considered for the present study. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Among nitrogen treatments, N_2 showed the best performance on seed yield and quality and gave the highest seed yield (1.79 t ha^{-1}), seed germination percentage (85.75%) and seed vigor index (1269.00) compared to other treatments. Among different phosphorus levels, P_2 gave the best results on seed yield and quality parameters and gave the highest seed yield ha^{-1} (1.85 g), seed germination percentage (85.18%) and seed vigor index (1261.00). Treatment combination of N_2P_2 registered the highest number of branches $plant^{-1}$ (22.40), pods $plant^{-1}$ (835.90), seed weight $plant^{-1}$ (20.88 g), 1000 seed weight (6.24 g), seed yield $plot^{-1}$ (501.10 g), seed yield ha^{-1} (2.32 t), stover yield ha^{-1} (3.04 t) and harvest index (43.28%). Regarding quality parameters, the highest seed germination (88.20%), shoot length (8.14 cm), root length (7.93 cm) and seed vigor index (1417.00) of seedlings after 12 days of germination were also recorded from the seeds produced from the treatment combination of N_2P_2. So, the treatment combination, N_2P_2 (90 kg N ha^{-1} with 30 kg P ha^{-1})) can be considered as best compared to other treatment combinations.

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ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro-Ecological Zone
BBS	:	Bangladesh Bureau of Statistics
BCSIR	:	Bangladesh Council of Scientific and Industrial Research
cm	:	Centimeter
CV %	:	Percent Coefficient of Variation
DAS	:	Days After Sowing
DMRT	:	Duncan's Multiple Range Test
et al.,	:	And others
e.g.	:	exempli gratia (L), for example
etc.	:	Etcetera
FAO	:	Food and Agriculture Organization of the United Nations
g	:	Gram (s)
i.e.	:	id est (L), that is
Kg	:	Kilogram (s)
LSD	:	Least Significant Difference
m^2	:	Meter squares
ml	:	MiliLitre
M.S.	:	Master of Science
No.	:	Number
SAU	:	Sher-e-Bangla Agricultural University
var.	:	Variety
^oC	:	Degree Celceous
%	:	Percentage
NaOH	:	Sodium hydroxide
GM	:	Geometric mean
mg	:	Miligram
P	:	Phosphorus
K	:	Potassium
Ca	:	Calcium
L	:	Litre
µg	:	Microgram
USA	:	United States of America
WHO	:	World Health Organization

CHAPTER I

INTRODUCTION

Water spinach (*Ipomoea aquatic*) commonly known as gimakalmi, is an important leafy vegetable belongs to the family Convolvulaceae cultivated in many tropical and subtropical regions around the world (Jayaweera *et al*., 2015; Sattar *et al*., 2011). Gimkalmi is a highly nutritious crop that is rich in protein, carbohydrates, vitamins, and minerals. However, the nutrient status of gimakalmi may vary depending on several factors such as soil type, environmental conditions, and management practices. Gimakalmi seeds are a rich source of protein (25-35%) and oil (16-20%) and contain significant amounts of carbohydrates, fiber, and minerals such as calcium, phosphorus, and iron (Singh *et al*., 2013). Similarly, the leaves of gimakalmi are also highly nutritious and contain significant amounts of protein (20-30%), vitamin C, and minerals such as calcium, magnesium, and potassium (Fauzi *et al*., 2019). The growth and yield of this crop are influenced by various factors, including the availability of essential nutrients like nitrogen and phosphorus. Nitrogen and phosphorus are two essential nutrients that play critical roles in the growth and development of this plant. The availability of these nutrients can affect the growth, vegetative yield, seed yield and quality of gimakalmi.

Gimakalmi is a very important leafy vegetable from the nutritional point of view. Like other leafy vegetable, it is nutritionally rich in vitamins, minerals, calories etc. Successful crop production mostly depends on the quality seeds and proper agronomic practices (BARC, 2012). At present gimakalmi is very popular vegetable. It is also a nutritious food for livestock. But most of the cases successful gimakalmi production is hampered due to lack quality seeds, moreover high purchase cost discourages farmers to produce gimakalmi. From this point of view gimakalmi seed production is needed for home consumption and also for commercial cultivation.

Nitrogen is an essential nutrient required for the growth and development of plants, and its availability can significantly affect the vegetative growth, seed yield and quality of gimakalmi. Nitrogen is a key component of chlorophyll, the pigment responsible for photosynthesis, and is required for the synthesis of amino acids and proteins. Several studies have investigated the effect of nitrogen on the growth and seed yield of gimakalmi, and these findings have important implications for the cultivation of this crop. Sison *et al.* (2019) evaluated that the increasing nitrogen levels significantly increased the number of pods per plant and seed yield, up to a certain threshold level beyond which further nitrogen application did not have a significant effect on seed yield. Oyewale *et al.* (2017) also found that the nitrogen application significantly increased the seed yield of gimakalmi, with the highest yield obtained at a rate of 90 kg N/ha.

Phosphorus is an essential macronutrient required for plant growth and development, and its availability can significantly influence the growth, seed yield and quality of crops. The increasing phosphorus levels significantly increased the growth and yield contributing parameters and seed yield, with the highest yield obtained at a rate of 60 kg P/ha (Singh *et al.*, 2013). Similarly, phosphorus application significantly increased the seed yield of gimakalmi, with the highest yield obtained at a rate of 60 kg P/ha (Oyewale *et al*., 2017).

However, the optimal rates of nitrogen and phosphorus fertilizers for water spinach (gimakalmi) cultivation may vary depending on the soil type and environmental conditions. A study by Lin *et al*. (2018) in Taiwan found that excessive application of nitrogen and phosphorus fertilizers led to a decrease in the growth and yield of water spinach in acidic soil. Another study by Dhanya *et al*. (2018) in India showed that the application of nitrogen and phosphorus at lower rates than the recommended levels resulted in higher yield and quality of water spinach (gimakalmi).

Furthermore, excessive use of nitrogen and phosphorus fertilizers can have negative impacts on the environment, such as eutrophication of water bodies and contamination of soil and groundwater (Yap *et al*., 2016). Excessive use of nitrogen and phosphorus fertilizers can also have negative impacts on the environment, such as water pollution and eutrophication (Zhang *et al*., 2020).

In conclusion, nitrogen and phosphorus are essential nutrients for the growth vegetative yield and seed yield of water spinach, but their application rates should be carefully managed to achieve maximum yield while minimizing negative environmental impacts. However, the application rates of nitrogen and phosphorus fertilizers should be carefully managed to balance the plant's nutrient requirements with environmental sustainability.

Therefore, it is important to determine the optimal rates of nitrogen and phosphorus fertilizers for gimakalmi cultivation to achieve maximum seed yield while minimizing the negative environmental impacts.

Objectives:

1. To find out the optimum nitrogen doses on growth, seed yield and quality of gimakalmi;
2. To evaluate the appropriate phosphorus doses on growth, seed yield and quality of gimakalmi; and
3. To determine the suitable combination of nitrogen and phosphorus on growth, seed yield and of quality gimakalmi.

CHAPTER II

REVIEW OF LITERATURE

Nitrogen and phosphorus plays an important role in the growth and seed yield of gimakalmi (*Ipomoea aquatica*), with increasing nitrogen and phosphorus levels generally leading to higher yields. However, the optimal nitrogen and phosphorus level for maximum yield may vary depending on factors such as soil type, climate, and management practices. The following literature reviews provide insights into the effects of different nitrogen and phosphorus levels on the growth and yield of gimakalmi, with some studies indicating positive effects on yield and quality with increased nitrogen application, while others suggesting that excessive nitrogen application can lead to negative impacts on plant growth and yield. Some of the important and informative works and research findings relevant to the topics was done at home and abroad has been reviewed under the following headings:

Effect of nitrogen on growth and seed yield of gimakalmi

Sharmin *et al*. (2021) conducted an experiment during August to October 2020 to investigate the response of different doses of nitrogen fertilizer on growth and yield of Kangkong (*Ipomoea reptans* poir). The experiment consisted of four nitrogen fertilizer levels *viz*. T_0: no fertilizer, T_1: 60 kg nitrogen fertilizer, T_2: 80 kg nitrogen fertilizer and T_3: 100 kg nitrogen fertilizer per hectare. The result revealed that plant height, number of leaves per plant, number of branches per plant, fresh weight per plant, dry weight per plant, root length per plant, fresh weight of root per plant, dry weight of root per plant, yield per plot and yield per hectare grown under different doses of nitrogen fertilizer *viz*. control (T_0), 60 kg N per hectare (T_1), 80 kg N per hectare (T_2), showed significant reduction than those grown in 100 kg N per hectare (T_3). The application of different doses of nitrogen significantly influences the growth and yield of Kangkong. The maximum plant height, number of leaves, number of branches, fresh weight per plant, root length was obtained from T_3 treatment while the minimum was found from the control treatment (T_0) at 60 days after sowing. The highest yield (17.87 t/ha) was performed from the treatment T_3 and the lowest yield (11.83 t/ha) was obtained from the control treatment where no nitrogen was used.

Gangaiah *et al*. (2021) observed that increasing nitrogen levels from 0 to 150 kg/ha led to increased seed yield of water spinach, with the highest yield obtained at a nitrogen level of 150 kg/ha.

Javed *et al*. (2021) found that application of nitrogen fertilizer significantly increased the pod yield and seed yield of water spinach, with the highest yield obtained at a nitrogen level of 160 kg/ha.

Dhakal *et al*. (2021) found that increasing nitrogen levels led to increased seed yield of water spinach, with the highest yield obtained at a nitrogen level of 200 kg/ha.

Kumar and Ghosh (2019a) found that application of nitrogen fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a nitrogen level of 100 kg/ha.

Islam *et al*. (2019) conducted an experiment during *rabi* season and reported that among four levels of nitrogen (N_0= 0 kg/ha N_1= 27.6 kg/ha, N_2=55.2 kg/ha, N_3= 82.8 kg/ha); the highest seed yield (1.10 t ha^{-1}), germination percentage (87.33%) and lowest value in EC test (11.87 dS/cm) were obtained from N_2, while the lowest seed yield (0.81 t ha^{-1}), germination percentage (79.33%) and highest value in EC test (13.87 dS/cm) from N_0.

Zhang *et al*. (2019) reported that increasing nitrogen levels led to increased pod yield, 1000 seed weight, seed yield and protein content of water spinach, with the highest yield obtained at a nitrogen level of 240 kg/ha.

Sison *et al*. (2019) conducted a study in the Philippines to evaluate the effect of different nitrogen levels on the growth and yield of gimakalmi. The results showed that increasing nitrogen levels significantly increased the number of pods per plant and seed yield, up to a certain threshold level beyond which further nitrogen application did not have a significant effect on yield.

El-Sayed and Abdel-Mawla (2018) reported that application of nitrogen fertilizer significantly increased the seed yield of water spinach, with the highest yield obtained at a nitrogen level of 100 kg/ha.

Kajjanavar *et al*. (2017) observed that increasing nitrogen levels from 60 to 120 kg/ha led to increased plant height, stem girth, and fresh and dry weight of water spinach, with the highest yield obtained at a nitrogen level of 120 kg/ha.

Reddy *et al*. (2017) found that increasing nitrogen levels led to increased plant height, leaf area, and yield of water spinach, with the highest yield obtained at a nitrogen level of 200 kg/ha.

Oyewale *et al*. (2017) conducted an experiment in Nigeria to study the effect of nitrogen on growth and seed yield of gimakalmi. The results showed that nitrogen application significantly increased the seed yield of gimakalmi, with the highest yield obtained at a rate of 90 kg N/ha.

Rizvi *et al*. (2016a) observed that increasing nitrogen levels led to increased plant height, leaf area, and yield of water spinach, with the highest yield obtained at a nitrogen level of 120 kg/ha.

Rahman *et al*. (2015b) reported that increasing nitrogen levels led to increased plant height, stem diameter, and yield of water spinach, with the highest yield obtained at a nitrogen level of 100 kg/ha.

Nahar *et al*. (2015) investigated the effect of different doses of nitrogen in combination with cowdung (CD) on the growth and yield of Gimakalmi. Single factor experiment consisted of four nitrogen-cowdung treatment combinations, i.e., 0 kg N + 0 ton CD ha^{-1} (without nitrogen and CD), 25 kg N + 5 ton CD ha^{-1}, 50 kg N + 10 ton CD ha^{-1} and 75 Kg N + 15 ton CD ha^{-1}. The results of the study revealed that higher doses of nitrogen with CD produced the tallest (30.22 cm), highest number of leaves and branches (160.64 and 21.81, respectively) $plant^{-1}$, fresh weight leaves and foliage (49.96 g and 58.39 g, respectively) $plant^{-1}$ as well as yield (6.92 t ha^{-1}).

Shrivastava *et al*. (2015) found that application of nitrogen and sulfur fertilizers significantly increased the growth and yield of water spinach, with the highest yield obtained at a nitrogen level of 150 kg/ha and a sulfur level of 30 kg/ha.

Mahanty *et al*. (2014) reported that increasing nitrogen levels led to increased plant height, leaf number, and yield of water spinach, with the highest yield obtained at a nitrogen level of 80 kg/ha compared to the nitrogen levels of 0, 20, 40 and 60 kg/ha.

Molla *et al*. (2013) observed that application of nitrogen fertilizer significantly increased the plant height, stem girth, and fresh and dry weight of water spinach, with the highest yield obtained at a nitrogen level of 120 kg/ha.

Eckert (2010) reported that increasing the levels of nitrogen during the vegetative stage can strengthen and allow a plant to grow more rapidly and produce large amounts of succulent, green foliage, which in turn can generate higher yields.

Choudhury *et al*. (2006) found that increasing nitrogen levels led to increased plant height, leaf area, and fresh and dry weight of water spinach, with the highest seed yield observed at a nitrogen level of 120 kg/ha. The maximum pod number and seed weight per plant were also achieved by the nitrogen level of 120 kg/ha compared to nitrogen level of 40 and 80 kg/ha whereas control (0 kg/ha) showed minimum pod yield and seed yield of water spinach.

Milford *et al*. (2005) reported that appropriate fertilizer application to the plants greatly affects their growth and production. Nitrogen strongly stimulates growth, expansion of the crop canopy and interception of solar radiation.

Ghosh and Bandyopadhyay (1990) reported that application of nitrogen fertilizer significantly increased the yield of water spinach, with the highest yield obtained at a nitrogen level of 150 kg/ha.

2.2 Effect of phosphorus on growth and seed yield of gimakalmi

Islam *et al*. (2019) conducted an experiment during *rabi* (November 2017 to March 2018) season. Results revealed that among four levels of phosphorus (P_0= 0 kg/ha; P_1 = 15.84 kg/ha, P_2 = 31.68 kg/ha, P_3= 47.52 kg/ha); treatment P_2 (31.68 kg/ha) gave the highest seed yield (1.05 t ha^{-1}), germination percentage (86.58%) and lowest value in EC test (11.79 dS/cm) of water spinach were recorded from P_2, whereas the lowest seed yield (0.84 t ha^{-1}), germination percentage (79.91%) and highest value in EC test (13.35 dS/cm) from P_0.

Kumar and Ghosh (2019b) observed that application of phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha.

Abbas *et al*. (2018) found that increasing phosphorus levels led to increased plant height, number of branches, seed yield per plant and seed yield per ha of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha compared to phosphorus levels of 0 and 30 kg/ha.

Zahid *et al*. (2017) found that application of phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha. Phosphorus level of 20 and 40 kg/ha gave lower yield of water spinach than 60 kg/ha phosphorus whereas control level (0 kg/ha) gave minimum growth and yield parameters.

Fakir *et al*. (2016) found that application of phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha compared to control (0 kg/ha). 30 kg P/ha also showed lower growth and yield parameters than 60 kg/ha phosphorus treatment.

Khan *et al*. (2016) reported that increasing phosphorus levels led to increased plant height, leaf area, pod number and seed weight per plant, and seed yield of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha.

Ali *et al*. (2015) observed that increasing phosphorus levels led to increased plant height, stem diameter, and seed yield of water spinach, with the highest yield obtained at a phosphorus level of 40 kg/ha than 20 and 30 kg P/ha while control (0 kg p/ha) level showed minimum yield of water spinach.

Rizvi *et al*. (2016b) observed that increasing phosphorus levels led to increased plant height, leaf area, and seed yield of water spinach, with the highest yield obtained at a phosphorus level of 50 kg/ha whereas 0 and 25 kg/ha phosphorus gave lower results.

Rahman *et al*. (2015a) reported that increasing phosphorus levels led to increased plant height, stem diameter, pod number per plant, seed weight per plant, 1000 seed weight and seed yield per ha of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha.

Ahmad *et al*. (2014) reported that application of phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a phosphorus level of 60 kg/ha whereas lower result was obtained from decreased level of phosphorus (0, 20 and 40 kg P/ha).

Mahanty *et al*. (2014) found that increasing phosphorus levels led to increased plant height, leaf number, and seed yield of water spinach, with the highest yield obtained at a phosphorus level of 45 kg/ha compared to phosphorus levels of 0, 15 and 30 kg/ha.

Griffiths (2010) reported that phosphorus (P) is an essential nutrient act as catalysts in the conversion of numerous key biochemical reactions in plants. Phosphorus stimulates root development, improves flower formation, seed production and improves crop quality and increases resistance to plant diseases.

Combined effect on nitrogen and phosphorus on growth and seed yield of gimakalmi

Miah *et al*. (2021) reported that the combined application of nitrogen and phosphorus fertilizer significantly increased the growth, yield, and yield components of water spinach, with the highest yield obtained at a combination of 150 kg/ha nitrogen and 60 kg/ha phosphorus.

A study conducted by Sudarshan *et al*. (2021) in India found that the application of nitrogen and phosphorus significantly increased the plant height, leaf area, and yield of water spinach. Similarly, a study by Arunrat *et al*. (2019) in Thailand showed that increasing nitrogen and phosphorus fertilization rates increased the yield and nutrient content of water spinach.

Rahman *et al*. (2020) reported that the application of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest seed yield obtained at a nitrogen level of 90 kg/ha and a phosphorus level of 45 kg/ha.

Wijayanti *et al*. (2020) reported that the combination of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest yield obtained at a nitrogen level of 120 kg/ha and a phosphorus level of 60 kg/ha.

Vien *et al*. (2020) observed that the combined application of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest seed yield obtained at a nitrogen level of 120 kg/ha and a phosphorus level of 30 kg/ha.

Khatun *et al*. (2020) found that the combined application of nitrogen and phosphorus fertilizer significantly increased the growth, yield, and quality of water spinach, with the highest yield obtained at a combination of 120 kg/ha nitrogen and 60 kg/ha phosphorus.

Zafar *et al*. (2019) reported that the combination of nitrogen and phosphorus significantly increased the seed yield of water spinach, with the highest yield obtained at a nitrogen level of 150 kg/ha and a phosphorus level of 75 kg/ha.

Ogbodo *et al*. (2019) observed that the combined application of nitrogen and phosphorus fertilizer significantly increased the yield and yield attributes of water spinach, with the highest yield obtained at a combination of 150 kg/ha nitrogen and 60 kg/ha phosphorus.

Okwukwe and Ezeaku (2019) found that the combined application of nitrogen and phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a combination of 120 kg/ha nitrogen and 60 kg/ha phosphorus.

Ndiema *et al*. (2019) found that the combination of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest yield obtained at a nitrogen level of 120 kg/ha and a phosphorus level of 60 kg/ha.

Adekiya *et al*. (2019) observed that the combined application of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest seed yield obtained at a nitrogen level of 150 kg/ha and a phosphorus level of 30 kg/ha.

Njiti *et al*. (2019) found that the combination of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest yield obtained at a nitrogen level of 180 kg/ha and a phosphorus level of 60 kg/ha.

Debnath and Islam (2019) reported that the combined application of nitrogen and phosphorus fertilizer significantly increased the yield and yield components of water spinach, with the highest yield obtained at a combination of 150 kg/ha nitrogen and 60 kg/ha phosphorus.

Hossain *et al*. (2019) observed that the combined application of nitrogen and phosphorus fertilizer significantly increased the yield and yield attributes of water spinach, with the highest yield obtained at a combination of 140 kg/ha nitrogen and 60 kg/ha phosphorus.

Sinthuja and Balasubramani (2019) observed that the combined application of nitrogen and phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a combination of 120 kg/ha nitrogen and 60 kg/ha phosphorus.

Islam *et al*. (2019) conducted an experiment during Rabi (November 2017 to March 2018) season to find out the growth, yield and economic benefit of spinach seed as influenced by nitrogen and phosphorus. The research involved two factors. Factor A: Four levels of nitrogen; N_0= 0 kg/ha N_1= 27.6 kg/ha, N_2=55.2 kg/ha, N_3= 82.8 kg/ha, and factor B: Four levels of phosphorus; P_0= 0 kg/ha; P_1 = 15.84 kg/ha, P_2= 31.68 kg/ha, P_3= 47.52 kg/ha. Among 16 treatment combinations, the highest seed yield (1.30 t ha^{-1}), germination percentage (91.33%) and lowest value in EC test (10.2 dS/cm) were noted from N_2P_2, whereas the lowest seed yield (0.69

t ha^{-1}), germination percentage (72.66%) and highest value in EC test (14.83 dS/cm) from N_0P_0.

Datta *et al*. (2018) found that the combination of nitrogen and phosphorus significantly increased the seed yield of water spinach, with the highest yield obtained at a nitrogen level of 150 kg/ha and a phosphorus level of 60 kg/ha.

Sarwar *et al*. (2018) observed that the combined application of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach, with the highest seed yield obtained at a nitrogen level of 150 kg/ha and a phosphorus level of 60 kg/ha.

Choudhary and Saini (2018) found that the application of nitrogen and phosphorus fertilizer significantly increased the growth, yield, and nutrient content of water spinach, with the highest yield obtained at a combination of 120 kg/ha nitrogen and 60 kg/ha phosphorus.

Sarker *et al*. (2018) reported that the combined application of nitrogen and phosphorus fertilizer significantly increased the growth and yield of water spinach, with the highest yield obtained at a combination of 140 kg/ha nitrogen and 60 kg/ha phosphorus.

Nwankwo and Ogbodo (2017) found that the combination of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach. The highest seed yield was obtained with the application of 150 kg/ha nitrogen and 30 kg/ha phosphorus.

Adekiya *et al*. (2016) observed that the combination of nitrogen and phosphorus fertilizer application significantly increased the growth and yield of water spinach, with the highest yield obtained at a combination of 150 kg/ha nitrogen and 60 kg/ha phosphorus.

A study conducted in Malaysia found that increasing nitrogen and phosphorus application rates increased the plant height, leaf area, and yield of gimakalmi (Nashriyah *et al.*, 2015). Similarly, a study conducted in Nigeria showed that the application of nitrogen and phosphorus significantly increased the vegetative yield and seed yield and nutrient content of gimakalmi (Akinboye *et al.*, 2016).

Assiouty *et al*. (2005) reported that application of 40 kg N + 15.0 kg P_2O_5 increased plant fresh yield by 27.2 and 42.3% and 16.3 and 10.4% in seed yield in relation to the control in the first and second seasons, respectively.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University. This chapter provided a brief description on location, climate, soil, crop, fertilizer, experimental design, cultural operations, collection of plant samples, materials used in the experiment and the methods followed and statistical analyses.

3.1 Experimental site

The research work was conducted at the Central Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the performance of gima kalmi seed production under different doses of nitrogen and phosphorus during the period from September 2021 to March 2022. Experimental field was located at 90°22/E longitude and 23°41/N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during “Kharif-1” season (April-September) and scarce rainfall, low humidity, low temperature and short day period during “Rabi” season (October-March). This climate is also characterized by distinct season, *viz.* the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.,* 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was medium high land and the soil series was Tejgaon (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100 g soil, respectively. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix III.

3.4 Planting materials

The materials used in the study was gimakalmi (cv. BARI gimakalmi-1).

3.5 Experimental treatments

The following treatments were included in the experiment:

Factor A: Nitrogen (Four levels of N ha^{-1})

1. N_0 = Control (no nitrogen)
2. N_1 = 60 kg N ha^{-1}
3. N_2 = 90 kg N ha^{-1}
4. N_3 = 120 kg N ha^{-1}

Factor B: Phosphorus (Four levels of P ha^{-1})

1. P_0 = Control (no phosphorus)
2. P_1 = 20 kg P ha^{-1}
3. P_2 = 30 kg P ha^{-1}
4. P_3 = 40 kg P ha^{-1}

There were 12 (3×4) treatment combinations given below:

N_0P_0, N_0P_1, N_0P_2, N_0P_3, N_1P_0, N_1P_1, N_1P_2, N_1P_3, N_2P_0, N_2P_1, N_2P_2, N_2P_3, N_3P_0, N_3P_1, N_3P_2 and N_3P_3.

3.6 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were 16 treatment combinations. In total of 48 unit plots and the size of each unit plot was 1.2 m × 1.8 m. The distance maintained between two replications and two plots were 1 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

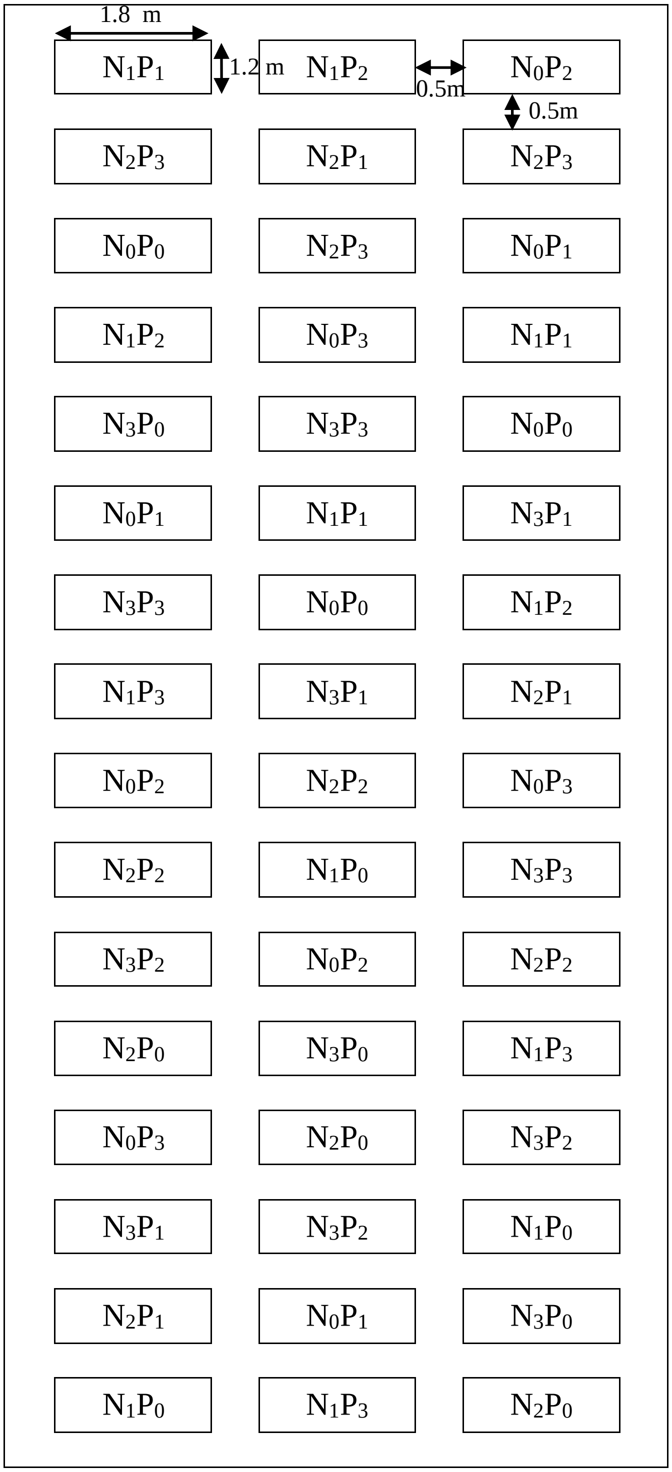
3.7 Land preparation

The land was first ploughed by a tractor drawn disc plough and subsequently cross ploughed four times with power tiller and ladder on 5 September, 2021. The corners of the land were spaded. It was then harrowed to bring the soil in a good tilth condition. The land was then thoroughly leveled by a ladder. Weeds and stubbles were removed from the field. All the clods were broken into small pieces. The unit plots were also prepared smoothly with spade before sowing.

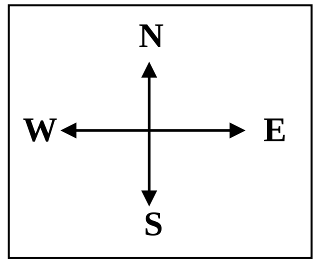
3.8 Fertilizer application

The fertilizers were applied as basal dose at final land preparation where Urea, TSP and MoP were applied by broadcasting and mixed thoroughly with soil. Urea and TSP were applied according to treatments assigned. The following doses of manure and fertilizers were used for the experiment:

Name of fertilizer and manure	Doses ha^{-1}
Cowdung	10 t
Urea	As per treatment
TSP	As per treatment
MoP	120 kg



Legend



Treatments

Factor A: Four levels of nitrogen

1. N_0 = Control (no nitrogen)
2. N_1 = 60 kg N ha^{-1}
3. N_2 = 90 kg N ha^{-1}
4. N_3 = 120 kg N ha^{-1}

Factor B: Four levels of phosphorus

1. P_0 = Control (no phosphorus)
2. P_1 = 20 kg P ha^{-1}
3. P_2 = 30 kg P ha^{-1}
4. P_3 = 40 kg P ha^{-1}

Fig. 1. Layout of the experimental plot

3.9 Sowing of seeds

Seeds were sown in each plot to obtain 1 plant in each hill which was done on 10 September, 2021. Two seeds were sown in each hill dipping to 2-3 cm maintaining the spacing of 30 cm × 30 cm and covered with soil properly. Extra plantation was done in order to gap filling if needed. After seedling establishment, 1 plant in each hill was kept by removing other plant from the hill.

3.10 Intercultural operation

3.10.1 Weed control

The crop was found to be infested with weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was given at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.10.2 Irrigation

The young plants were irrigated by a watering can and at later stage irrigation was done by flooding of each plot whenever necessary. Stagnant water was drained out at the time of heavy rain.

3.10.3 Plant protection

For controlling leaf caterpillars diazinon @ 1 ml/L water were applied 2 times at an interval of 10 days starting soon after the appearance of infestation. There was no appreciable attack of disease

3.11 Harvesting

The harvest was done from all plots at 150 days after sowing of gimakalmi seeds. The border plants were not included at harvest. When plants were turned into gray yellow color, the matured gimakalmi pods were harvested on 17th February 2022.

3.12 Threshing, cleaning, drying and storage

Harvested gimakalmi pods were dried on the cemented floor under sunlight. The seeds were threshed by beating the pods with small stick. Seeds were then cleaned by winnowing manually and dried by spreading in the open sunlight on brown paper. The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level (6-9%). The dried seeds and straw were cleaned and weighed. After putting the seeds in airtight polythene bags, these were kept in dry and cool place at room temperature for storing.

Plate 1. Preparation of experiment field

Plate 2. Sowing of seeds in the experiment field

Plate 3. Emergence of seedlings in the experiment plot

Plate 4. Experiment field view at vegetative stage

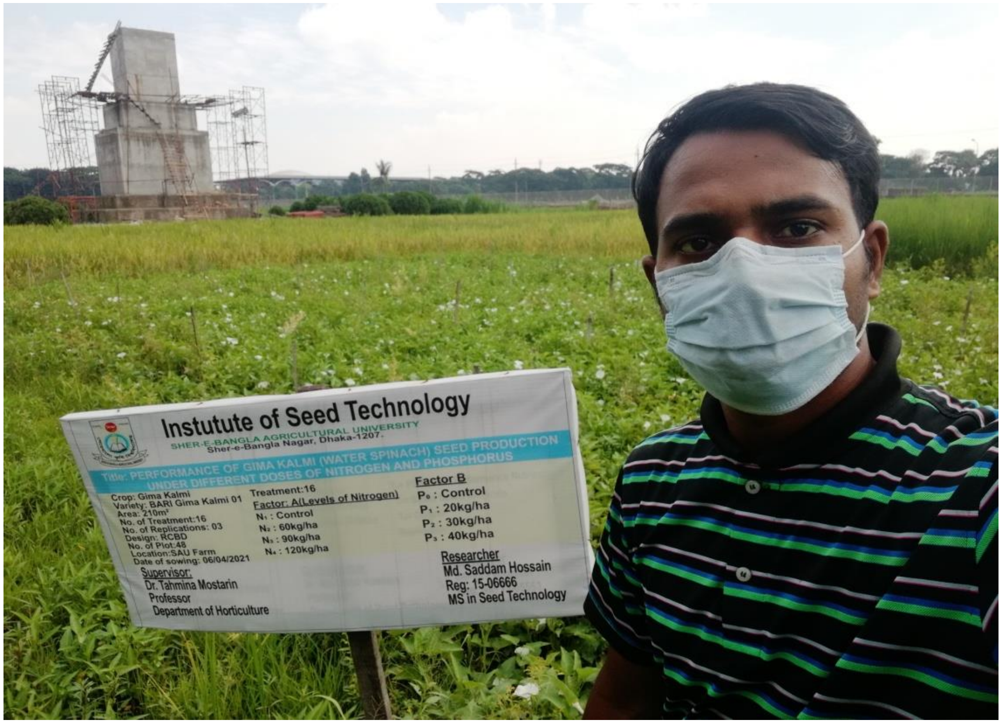


Plate 5. Experiment field view with signboard at flowering stage

Plate 6. Data collection at flowering stage

3.13 Seed quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality test in the laboratory. For this purpose standard germination test was conducted and other different quality attributes data were taken.

3.14 Collection of data

The data were recorded on the following parameters:

3.14.1 Growth parameters

1. Plant height
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

3.14.2 Yield contributing parameters

1. Number of pods plant^{-1}
2. Seed weight plant^{-1}
3. 1000 seed weight

3.14.3 Yield parameters

1. Seed yield plot^{-1}
2. Seed yield ha^{-1}

3.14.4 Seed quality parameters

1. Germination (%)
2. Shoot length
3. Root length
4. Seed vigour index

3.15 Procedure of data

Data on the following characters were collected from experimental plots and selected plants.

3. 15.1 Plant height

Plant height was measured from the ten randomly selected plants in centimeter from the ground level to the tip of the stem at 30, 60, 90 days after sowing. Mean highest was them calculated.

3. 15.2 Number of leaves plant^{-1}

The number of leaves was counted at 30, 60 and 90 days after sowing from the ten randomly selected plants and their average was calculated as the number of leaves per plant.

3. 15.3 Number of branches plant^{-1}

The number of branches was counted at 30, 60 and 90 days after sowing from ten randomly selected plants and their average was calculated.

3. 15.3 Number of pods plant^{-1}

Number of pods plant^{-1} was counted from the 10 randomly selected plants from each plot and then the average pod number was calculated.

3. 15.8 Seed weight plant^{-1}

The 10 plants were selected randomly from the inner rows of each plot which were harvested to take seed yield per plant. Seeds were then threshed, cleaned, dried, weighed and then average seed weight was taken in gram (g).

3. 15.7 Weight of 1000 seeds

1000 seeds were counted randomly, which were taken from the seeds sample of each plot separately, then weighed with the help of an electrical balance and data were recorded in gram (g).

3. 15.9 Seed yield plot^{-1}

All plots were harvested individually. Seed weight per plot was recorded. Average yield was recorded from three replication. Seed yield of seeds plot^{-1} was recorded in kilogram (kg).

3. 15.10 Seed yield ha^{-1}

The yield of seed in kg per plot was adjusted at 12% moisture content of seed and then it was converted to kg per hectare.

3. 15.11 Seed viability test

3. 15.11.1 Percent (%) seed germination

After collection of harvested seeds, percent seedling emergence was tested in the Laboratory. Sample seeds from each replication collected from the experiment field were tested for percent seed germination. Germination was calculated as the number of seeds which was germinated within 12 days as a proportion of number of seeds set for germination test in each treatment.

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds set for germination}} \times 100$$

3.15.11.2 Root length

The Root length of five seedlings from each sample was recorded finally at 12 days of germination test. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.15.11.3 Shoot length

The shoot length of ten seedlings from each sample was measured finally at 12 days of germination test. Measurement was done using the unit centimeter (cm) by a meter scale.

3.15.11.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = (RL+SL) \times GP,$$

Where

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.16 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was carried out to find the effect of nitrogen and phosphorus on growth and seed yield of gimakalmi. The results have been presented through tables and figures. Different parameters of the gimakalmi cultivar influenced by nitrogen (N) and phosphorus (P) have been presented and discussed under separate heads and sub–heads as follows:

4.1 Growth parameters

4.1.1 Plant height

Plant height of gimakalmi significantly influenced of different nitrogen (N) treatments at different days after sowing (DAS) (30-90 days) (Appendix IV). At 90 DAS, the maximum plant height (38.47 cm) was recorded from the treatment N_3 (120 kg N ha^{-1}) followed by the treatment N_2 (90 kg N ha^{-1}) at all growth stages whereas the minimum plant height (25.92 cm) was found from the treatment N_0 (control; no nitrogen) (Fig. 2). Choudhury *et al*. (2006) and Kajjanavar *et al*. (2017) also found similar result with the present study and found significant difference among different nitrogen treatments and achieved higher plant height with 120 kg N nitrogen per ha.

There was significant difference among the different treatments of phosphorus (P) regarding plant height of gimakalmi at different growth stages (DAS) (30-90 DAS) (Appendix IV). Results indicated that at 90 DAS, the maximum plant height (35.15 cm) was recorded from the treatment P_3 (40 kg P ha^{-1}) followed by the treatment P_2 (30 kg P ha^{-1}) at all growth stages whereas the minimum plant height (29.47 cm) was found from the treatment P_0 (control; no phosphorus) (Fig. 3). The result obtained from the present study was similar with the findings of Abbas *et al*. (2018), Khan *et al*. (2016) and Ali *et al*. (2015).

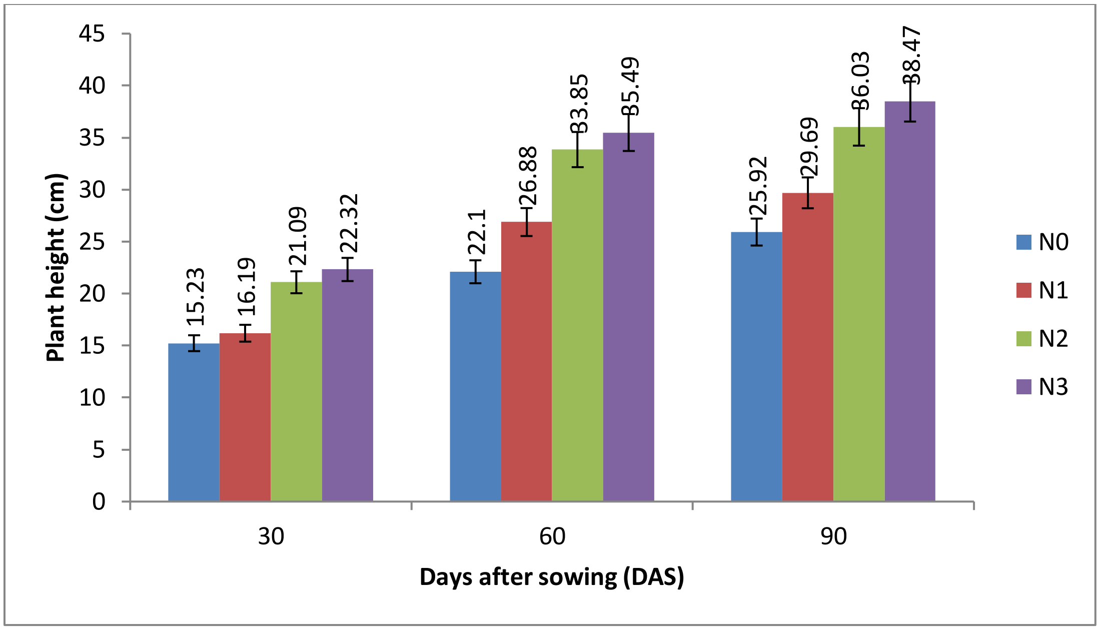


Fig. 2. Plant height of gimakalmi as influenced by different nitrogen levels

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

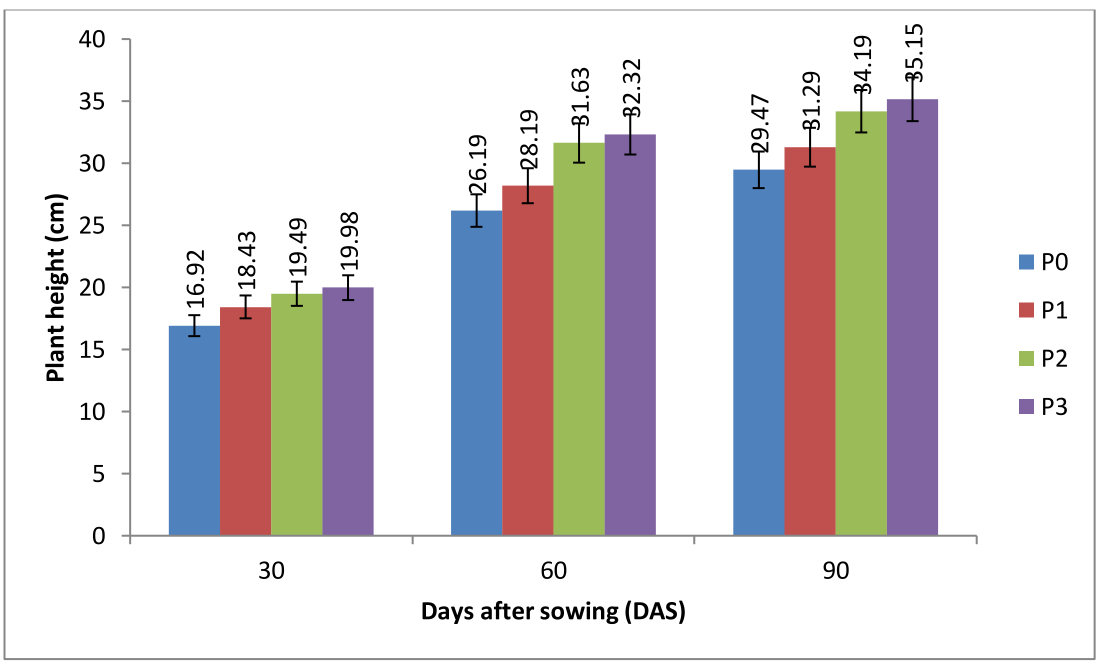


Fig. 3. Plant height of gimakalmi as influenced by different phosphorus levels

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

The treatment combinations of nitrogen (N) and phosphorus (P) had significant effect on plant height of gimakalmi at 30 to 90 DAS (days after sowing) (Appendix IV). Results showed that at 90 DAS, the maximum plant height (41.44 cm) was achieved by the treatment combination of N_3P_3 (120 kg N + 40 kg P) which was statistically identical to N_3P_2 and the minimum plant height (22.04 cm) was found from the treatment combination of N_0P_0 (control treatment) (Table 1).

Table 1. Plant height of gimakalmi as influenced by different combinations of nitrogen and phosphorus

Treatments	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
N_0P_0	14.80 f	18.60 j	22.04 h
N_0P_1	15.12 f	19.52 j	24.76 g
N_0P_2	15.40 f	24.80 h	27.87 ef
N_0P_3	15.60 f	25.47 h	28.99 e
N_1P_0	15.30 f	23.20 i	27.04 f
N_1P_1	16.14 f	26.72 g	29.14 e
N_1P_2	16.52 ef	28.40 f	31.04 d
N_1P_3	16.78 ef	29.20 f	31.54 d
N_2P_0	18.64 de	30.70 e	33.87 c
N_2P_1	20.84 cd	32.80 c	34.36 c
N_2P_2	22.12 bc	35.70 b	37.24 b
N_2P_3	22.75 abc	36.20 b	38.64 b
N_3P_0	18.94 de	32.24 cd	34.94 c
N_3P_1	21.63 bc	33.70 c	36.88 b
N_3P_2	23.92 ab	37.60 a	40.60 a
N_3P_3	24.80 a	38.40 a	41.44 a
$LSD_{0.05}$	2.478	1.012	1.791
CV(%)	6.72	10.24	12.63

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

4.1.2 Number of leaves plant^{-1}

Different treatment of nitrogen (N) at different growth stages showed significant variation on number of leaves plant^{-1} at different days after sowing (30-90 DAS) (Appendix V). At 90 DAS, the highest number of leaves plant^{-1} (156.75) was recorded from the treatment N_3 (120 kg N ha^{-1}) followed by the treatment N_2 (90 kg N ha^{-1}). Again, the lowest number of leaves plant^{-1} (131.20) was recorded from the treatment N_0 (control; no nitrogen) (Fig. 4). Similar result was also observed by the study of Mahanty *et al*. (2014) and Nahar *et al*. (2015). Mahanty *et al*. (2014) achieved higher leaf number from the nitrogen levels of 80 kg/ha compared to the nitrogen levels of 0, 20, 40 and 60 kg/ha which supported the present findings.

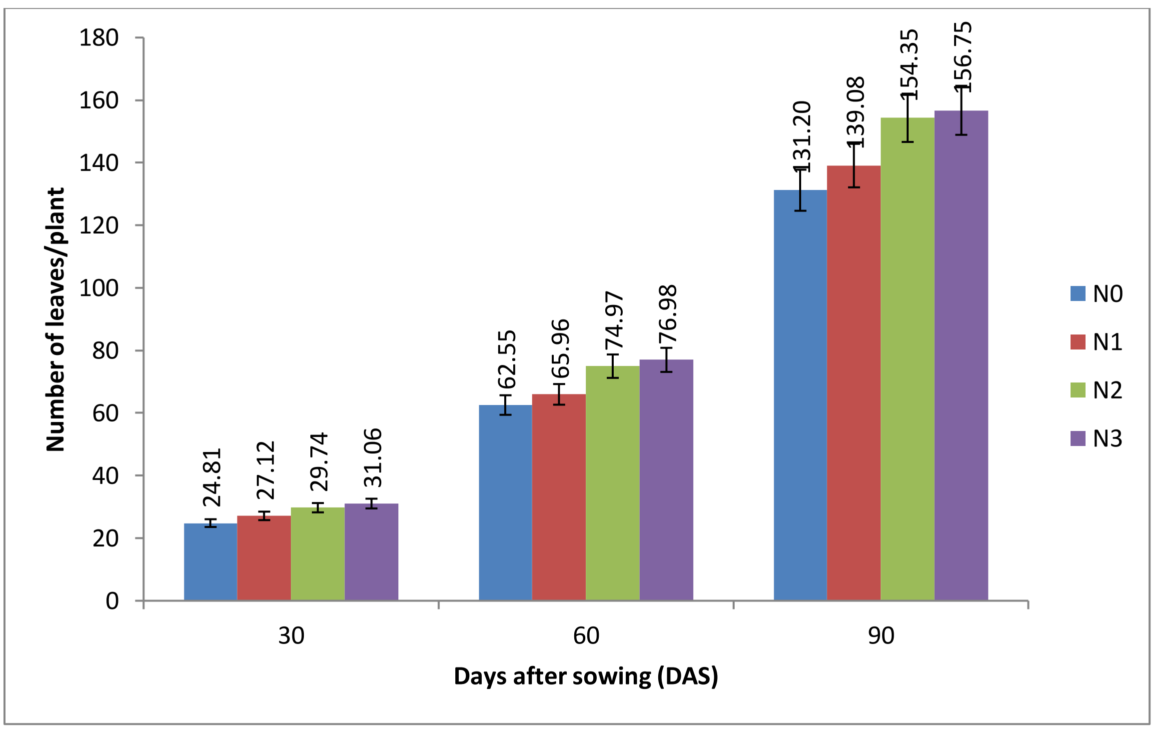


Fig. 4. Number of leaves plant^{-1} of gimakalmi as influenced by different nitrogen levels

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

Number of leaves plant^{-1} of gimakalmi was influenced significantly due to application of different doses of phosphorus (P) at different days after sowing (30-90 DAS) (Appendix V). Results indicated that at 90 DAS the treatment P_3 (40 kg P ha^{-1}) showed the highest number of leaves plant^{-1} (151.15) which was statistically similar with P_2 (30 kg P ha^{-1}). The treatment P_0 (control; no phosphorus) showed the lowest number of leaves plant^{-1} (137.90) that was significantly different from other treatments (Fig. 5). This result suggested that variation on phosphorus doses showed significant variation on leaf number of gimakalmi higher leaf number was obtained with higher P doses which was supported by the findings of Rizvi *et al*. (2016a), Mahanty *et al*. (2014) and Khan *et al*. (2016); they found significant variation on leaf number due to variation on different doses of phosphorus.

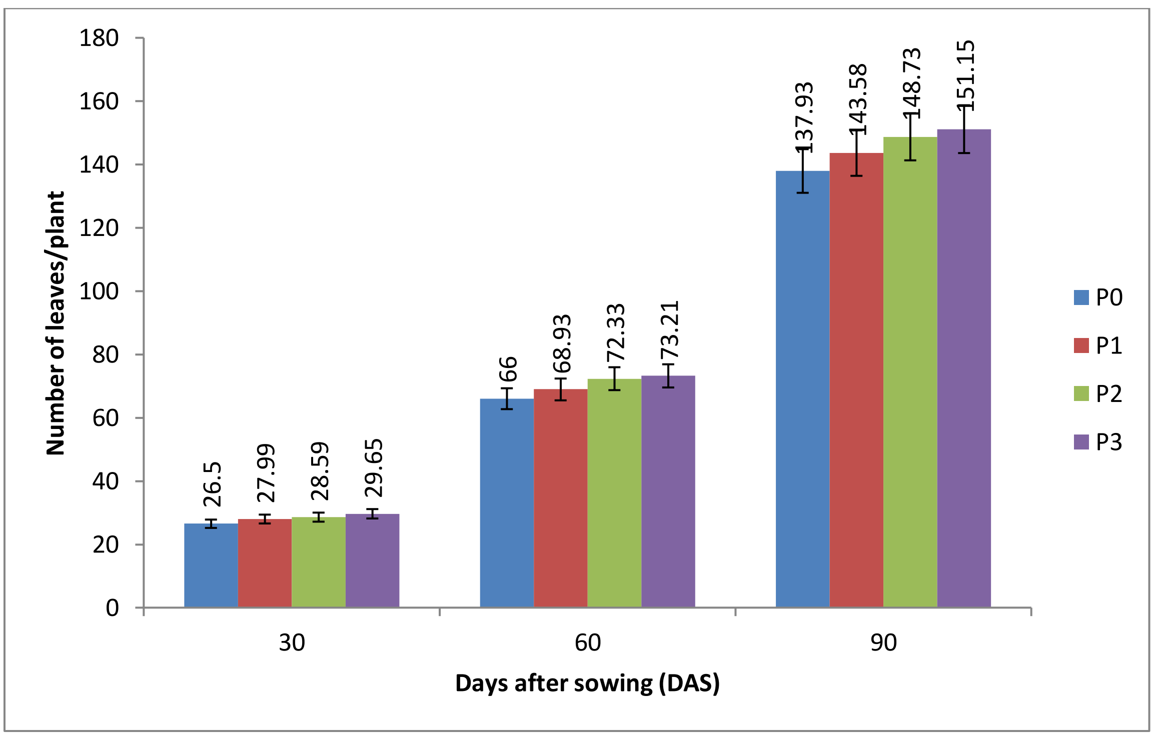


Fig. 5. Number of leaves plant^{-1} of gimakalmi as influenced by different phosphorus levels

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

Table 2. Number of leaves plant^{-1} of gimakalmi as influenced by different treatment combinations of nitrogen and phosphorus

Treatments	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
N_0P_0	23.80 g	60.30 i	122.90 j
N_0P_1	24.60 fg	60.48 i	128.40 i
N_0P_2	25.24 fg	64.12 gh	135.80 gh
N_0P_3	25.60 f	65.30 fg	137.70 gh
N_1P_0	25.10 fg	62.74 hi	134.20 h
N_1P_1	27.64 e	66.36 fg	138.30 gh
N_1P_2	27.72 e	66.94 f	140.60 fg
N_1P_3	28.00 de	67.80 f	143.20 ef
N_2P_0	28.30 de	70.42 e	145.90 de
N_2P_1	29.60 bcd	73.24 d	152.40 bc
N_2P_2	30.27 bc	77.90 bc	158.70 ab
N_2P_3	30.80 b	78.32 b	160.40 ab
N_3P_0	28.80 cde	70.52 e	148.70 cd
N_3P_1	30.12 bc	75.63 cd	155.20 b
N_3P_2	31.12 b	80.36 ab	159.80 ab
N_3P_3	34.20 a	81.40 a	163.30 a
$LSD_{0.05}$	1.759	2.539	4.836
CV(%)	5.84	9.63	11.58

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

Different combinations of nitrogen (N) and phosphorus (P) gave statistically significant influence on number of leaves plant^{-1} of gimakalmi at different growth stages (Appendix V). Results indicated that at 90 DAS, the highest number of leaves plant^{-1} (163.30) was recorded from the treatment combination of N_3P_3 (120 kg N + 40 kg P) which was statistically similar to the treatment combination of

N_2P_2, N_2P_3 and N_3P_2 (Table 2). On the other hand, at 90 DAS, the lowest number of leaves plant^{-1} (122.90) was found from the treatment combination of N_0P_0 (control treatment) that was significantly different to other treatment combinations. This result indicated that control treatment gave lower leaf number due to cause of lower physiological activities such as photosynthesis, nutrient uptake etc. due to lack of nutrient availability while available nitrogen and phosphorus in soil resulted higher photosynthesis and other physiological activity which might ensured higher leaf number.

4.1.3 Number of branches plant^{-1}

There was a significant variation on number of branches plant^{-1} of gimakalmi at different days after sowing (30-90 DAS) influenced by different levels of nitrogen (N) (Appendix VI). At 90 DAS, the highest number of branches plant^{-1} (20.16) was recorded from the treatment N_2 (90 kg N ha^{-1}) that was statistically similar to the treatment N_3 (120 kg N ha^{-1}). The lowest number of branches plant^{-1} at 90 DAS (14.91) was recorded from the treatment N_0 (control; no nitrogen) that was significantly different to other treatments (Fig. 6). This result indicated that higher N doses contributed to higher branches number to at a certain level. Sharmin *et al*. (2021) and Nahar *et al*. (2015) found similar result with the present study and obtained significant variation on number of branches plant^{-1} of gimakalmi among different treatments of nitrogen.

Significant variation was observed on number of branches plant^{-1} of gimakalmi at different days after sowing (30-90 DAS) influenced by different levels of phosphorus (P) (Appendix VI). It was observed that at 90 DAS, the treatment P_2 (30 kg P ha^{-1}) gave the highest number of branches plant^{-1} (19.69) which was statistically identical with P_3 (40 kg P ha^{-1}) at all growth stages. Again, the treatment P_0 (control; no phosphorus) showed the lowest number of branches plant^{-1} at 90 DAS (15.69) that was significantly different from other treatments (Fig. 7). Abbas *et al*. (2018) also reported similar result with the present study.

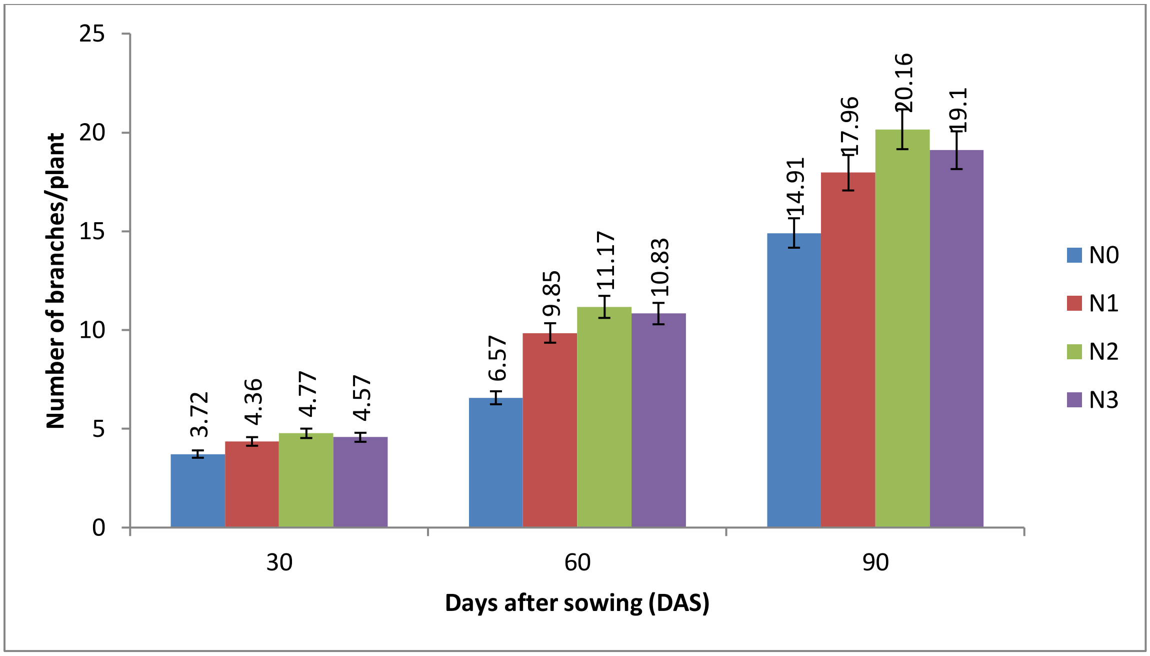


Fig. 6. Number of branches plant^{-1} of gimakalmi as influenced by different nitrogen levels

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

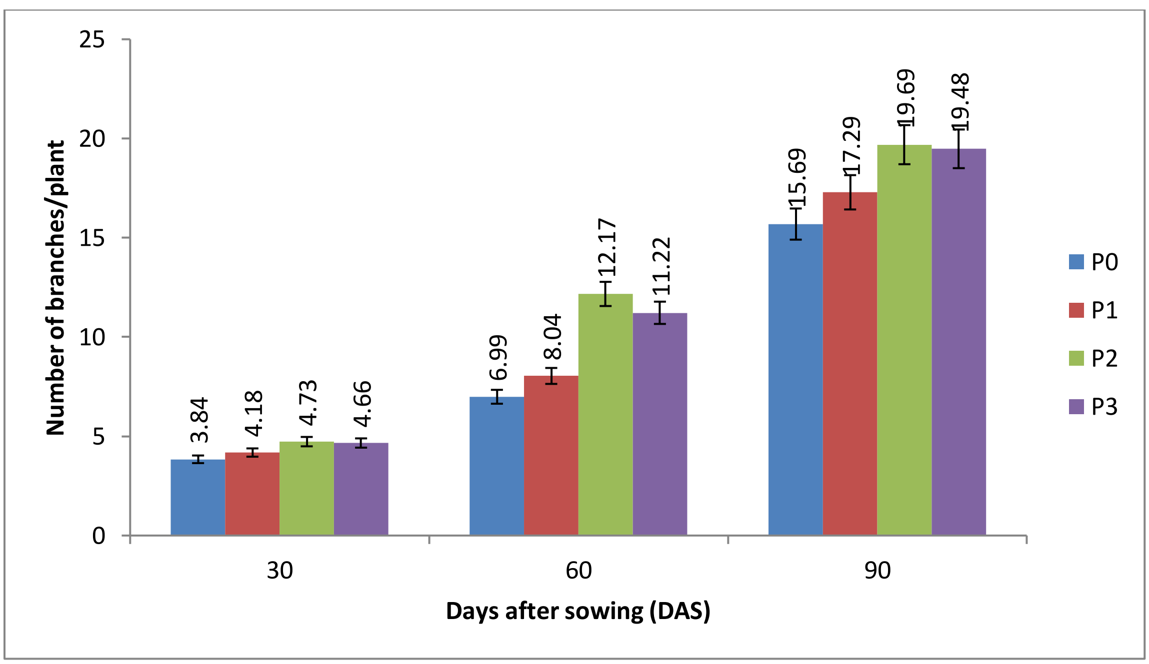


Fig. 7. Number of branches plant^{-1} of gimakalmi as influenced by different phosphorus levels

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

Significant influence was found on number of branches plant^{-1} of gimakalmi at different days after sowing (30-90 DAS) affected by treatment combinations of nitrogen (N) and phosphorus (P) (Appendix VI). Results exposed that the highest number of branches plant^{-1} (22.40) at 90 DAS was recorded from the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) which was statistically identical to N_3P_2 and similar to N_2P_3. On the other hand, the lowest number of branches plant^{-1} (14.20) at 90 DAS was recorded from the treatment combination of N_0P_0 (control treatment) that was statistically identical to N_0P_1 and N_1P_0 treatment combinations and similar to N_0P_2 and N_0P_3 (Table 3).

Table 3. Number of branches plant^{-1} of gimakalmi as influenced by different treatment combinations of nitrogen and phosphorus

Treatments	Number of branches plant^{-1}		
	30 DAS	60 DAS	90 DAS
N_0P_0	3.58 g	6.20 i	14.20 g
N_0P_1	3.60 g	6.24 i	14.62 g
N_0P_2	3.88 efg	7.00 ghi	15.47 fg
N_0P_3	3.80 fg	6.83 ghi	15.36 fg
N_1P_0	3.75 fg	6.72 hi	15.12 g
N_1P_1	4.14 de	8.27 ef	17.50 e
N_1P_2	4.80 bc	12.30 cd	19.75 cd
N_1P_3	4.75 bc	12.10 d	19.48 d
N_2P_0	4.04 def	7.72 fg	16.80 e
N_2P_1	4.72 c	8.87 e	19.20 d
N_2P_2	5.20 a	15.88 a	22.40 a
N_2P_3	5.12 a	13.24 bc	21.15 ab
N_3P_0	3.97 def	7.30 gh	16.63 ef
N_3P_1	4.27 d	8.78 e	17.82 e
N_3P_2	5.05 ab	13.50 b	22.20 a
N_3P_3	4.98 abc	12.72 bcd	20.84 bc
$LSD_{0.05}$	0.303	0.945	1.327
CV(%)	4.89	7.92	10.36

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}
P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

4.2 Yield contributing parameters

4.2.2 Number of pods plant^{-1}

Number of pods plant^{-1} of gimakalmi affected significantly due to different nitrogen (N) doses (Appendix VII). Results showed that at harvest the highest number of pods plant^{-1} (676.40) was recorded from the treatment N_2 (90 kg N ha^{-1}) followed by N_3 (120 kg N ha^{-1}) whereas the lowest number of pods plant^{-1} (268.30) was recorded from treatment N_0 (control; no nitrogen) (Table 4). Sison *et al*. (2019) reported that increasing nitrogen levels significantly increased the number of pods per plant, up to a certain threshold level which supported the present findings. Javed *et al*. (2021) also found similar result with the present study.

Application of different levels of phosphorus (P) showed significant effect on number of pods plant^{-1} of gimakalmi (Appendix VII). Results showed that the highest number of pods plant^{-1} (679.20) was recorded from the treatment P_2 (30 kg P ha^{-1}) that was significantly different to other treatments followed by P_3 (40 kg P ha^{-1}) whereas the lowest number of pods plant^{-1} (319.00) was recorded from the treatment P_0 (control; no phosphorus) that was significantly different with other treatments (Table 4). Supported result was also found from the findings of Khan *et al*. (2016) who reported that increasing phosphorus levels led to increased pod number per plant and pod yield obtained at a phosphorus level of 60 kg/ha which supported the present findings.

Number of pods plant^{-1} of gimakalmi influenced significantly due to different treatment combinations of nitrogen (N) and phosphorus (P) (Appendix VII). It was found that the highest number of pods plant^{-1} (835.90) was recorded from the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) followed by N_2P_3. The lowest number of pods plant^{-1} (220.80) was recorded from the treatment combination of N_0P_0 (control treatment) which was significantly differed to other treatment combinations (Table 4).

4.2.2 Seed weight plant^{-1}

Seed weight plant^{-1} of gimakalmi affected significantly due to different nitrogen (N) treatments (Appendix VIII). Results showed that the highest seed weight plant^{-1} (16.06 g) was recorded from the treatment N_2 (90 kg N ha^{-1}) followed by the treatment N_3 (120 kg N ha^{-1}) whereas the lowest seed weight plant^{-1} (6.37 g) was recorded from the N_0 (control; no nitrogen) treatment (Table 4). This result was in agreement with the findings of Choudhury *et al*. (2006) who achieved higher seed weight per plant at a nitrogen level of 120 kg/ha compared to nitrogen level of 40 and 80 kg/ha.

Application of different levels of phosphorus (P) gave significant effect on seed weight plant^{-1} of gimakalmi (Appendix VIII). Results exhibited that the highest seed weight plant^{-1} (16.63 g) was recorded from the treatment P_2 (30 kg P ha^{-1}) followed by the treatment P_3 (40 kg P ha^{-1}) whereas the lowest seed weight plant^{-1} (6.95 g) was recorded from the treatment P_0 (control; no phosphorus) (Table 4). Similar result was also observed by the findings of Abbas *et al*. (2018) who reported significantly higher seed weight of water spinach per plant with the application of phosphorus (P) at higher levels (60 kg/ha) compared to control.

Seed weight plant^{-1} of gimakalmi influenced significantly due to different combination of nitrogen (N) and phosphorus (P) levels (Appendix VIII). Results showed that the highest seed weight plant^{-1} (20.88 g) was recorded from the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) followed by N_2P_3. The lowest seed weight plant^{-1} (4.68 g) was recorded from the treatment combination of N_0P_0 which was significantly different from other treatment combinations (Table 4). The combination of nitrogen at 90 kg ha^{-1} and phosphorus at 30 kg ha^{-1} probably provided a balanced ratio of N:P, which might be the cause for promoting healthy plant growth and seed development. Imbalances in nutrient ratios can lead to reduced plant productivity and seed yield (Johnson *et al*., 2018).

Table 4. Yield contributing parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Treatments	Yield contributing parameters		
	Number of pods plant^{-1}	Seed weight plant^{-1} (g)	1000 seed weight (g)
Effect of nitrogen			
N_0	268.30 d	6.37 d	5.41 b
N_1	582.20 c	13.61 c	5.77 a
N_2	676.40 a	16.06 a	5.93 a
N_3	659.30 b	14.96 b	5.82 a
$LSD_{0.05}$	15.55	0.988	0.242
CV(%)	11.27	8.52	6.73
Effect of phosphorus			
P_0	319.90 d	6.95 d	5.44 c
P_1	519.30 c	11.93 c	5.69 b
P_2	679.20 a	16.63 a	5.95 a
P_3	667.80 b	15.50 b	5.88 a
$LSD_{0.05}$	13.51	0.827	0.158
CV(%)	11.27	8.52	6.73
Combined effect of nitrogen and phosphorus			
N_0P_0	220.80 l	4.68 j	5.30 g
N_0P_1	260.70 k	5.67 i	5.42 fg
N_0P_2	250.20 k	7.65 gh	5.47 f
N_0P_3	341.60 i	7.47 h	5.45 fg
N_1P_0	298.50 j	6.48 i	5.44 fg
N_1P_1	515.40 g	11.88 f	5.75 e
N_1P_2	770.00 c	18.36 d	5.96 c
N_1P_3	745.00 d	17.73 d	5.93 cd
N_2P_0	385.20 h	8.46 g	5.52 f
N_2P_1	665.80 e	15.48 e	5.80 de
N_2P_2	835.90 a	20.88 a	6.24 a
N_2P_3	818.60 b	19.43 b	6.16 ab
N_3P_0	375.20 h	8.19 gh	5.50 f
N_3P_1	635.50 f	14.67 e	5.78 de
N_3P_2	815.10 b	19.62 bc	6.03 bc
N_3P_3	811.60 b	17.35 d	5.97 c
$LSD_{0.05}$	15.25	0.945	0.158
CV(%)	11.27	8.52	6.73

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}
P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

4.2.3 Weight of 1000 seeds

Significant variation was found for 1000 seed weight of gimakalmi as influenced by nitrogen (N) treatments (Appendix VII). The highest 1000 seed weight (5.93 g) was recorded from the treatment N_2 (90 kg N ha^{-1}) which was statistically identical to the treatment N_3 (120 kg N ha^{-1}) and N_1 (60 kg N ha^{-1}) whereas the lowest 1000 seed weight (5.41 g) was recorded from the treatment N_0 (control; no nitrogen) (Table 4). Zhang *et al*. (2019) also found similar result with the present study and reported that increasing nitrogen levels led to increased 1000 seed weight of water spinach.

Different phosphorus (P) levels showed significant variation on 1000 seed weight of gimakalmi (Appendix VII). The treatment P_2 (30 kg P ha^{-1}) gave the highest 1000 seed weight (5.95 g) which was statistically identical to the treatment P_3 (40 kg P ha^{-1}) whereas the treatment P_0 (control; no phosphorus) showed the lowest 1000 seed weight (5.44 g) (Table 4). Rahman *et al.* (2015) also observed similar result in water spinach with the present study.

Significant influence was found on 1000 seed weight of gimakalmi as influenced by combined effect of different nitrogen (N) and phosphorus (P) levels (Table 4 and Appendix VII). The highest 1000 seed weight (6.24 g) was recorded from the treatment combination of N_2P_2 which was statistically similar to the treatment combination of N_2P_3 whereas the lowest 1000 seed weight (5.30 g) was recorded from the treatment combination of N_0P_1, N_0P_3 and N_1P_0.

4.3 Yield parameters

4.3.1 Seed yield plot^{-1} (g)

Gimakalmi seed yield plot^{-1} affected significantly by different doses of nitrogen (N) (Appendix VIII). The highest seed yield plot^{-1} (387.50 g) was recorded from the treatment N_2 (90 kg N ha^{-1}) whereas the lowest seed yield plot^{-1} (152.80 g) was recorded from the treatment N_0 (control; no nitrogen) (Table 5). Sharmin *et al*. (2021) also found similar result with the present study.

Different phosphorus (P) doses showed significant effect on seed yield plot^{-1} of gimakalmi (Appendix VIII). The highest seed yield plot^{-1} (399.10 g) was recorded from the treatment P_2 (30 kg P ha^{-1}) followed by the treatment P_3 (40 kg P ha^{-1}) whereas the lowest seed yield plot^{-1} (166.90 g) was recorded from the P_0 (control; no phosphorus) treatment which was significantly different from other treatments (Table 5).

Seed yield plot^{-1} of gimakalmi influenced significantly by different treatment combinations of nitrogen (N) and phosphorus (P) (Appendix VIII). Results showed that the highest seed yield plot^{-1} (501.10 g) was recorded from the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) and the lowest seed yield (112.30 g) was recorded from the treatment combination of N_0P_0 (control treatment) which was significantly different from other treatment combinations (Table 5). Probably the combination of 90 kg/ha N and 30 kg/ha P striked a balance between nutrient application which provided sufficient nutrients to support seed production without excessive use of fertilizers. Higher levels of N and P can increase the overall yield potential, but excessive application can lead to nutrient imbalances and potential wastage (Chen *et al*., 2020).

Table 5. Yield parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Treatments	Yield parameters			
	Seed yield plot^{-1} (g)	Seed yield ha^{-1} (t)	Stover yield ha^{-1} (t)	Harvest index (%)
Effect of nitrogen				
N_0	152.80 d	0.71 d	1.42 d	33.03 d
N_1	326.70 c	1.51 c	2.37 c	37.00 c
N_2	387.50 a	1.79 a	2.62 a	39.53 a
N_3	371.00 b	1.69 b	2.52 b	38.92 b
$LSD_{0.05}$	11.51	0.088	0.083	0.428
CV(%)	9.24	9.27	11.48	10.60
Effect of phosphorus				
P_0	166.90 d	0.77 d	1.55 d	33.05 d
P_1	286.20 c	1.33 c	2.24 c	36.54 c
P_2	399.10 a	1.85 a	2.61 a	39.96 b
P_3	385.90 b	1.76 b	2.53 b	38.93 a
$LSD_{0.05}$	11.26	0.079	0.076	0.644
CV(%)	9.24	9.27	11.48	10.60
Combined effect of nitrogen and phosphorus				
N_0P_0	112.30 l	0.52 j	1.16 i	30.95 f
N_0P_1	136.10 k	0.63 ij	1.28 hi	32.98 e
N_0P_2	183.60 i	0.85 g	1.67 efg	33.73 de
N_0P_3	179.30 i	0.83 gh	1.58 fg	34.44 de
N_1P_0	155.50 j	0.72 hi	1.44 gh	33.33 e
N_1P_1	285.10 g	1.32 f	2.44 d	35.11 d
N_1P_2	440.60 c	2.04 cd	2.81 abc	41.06 b
N_1P_3	425.50 d	1.97 d	2.78 bc	38.47 c
N_2P_0	203.00 h	0.94 g	1.83 e	33.94 de
N_2P_1	371.50 e	1.72 e	2.63 cd	39.54 c
N_2P_2	501.10 a	2.32 a	3.04 a	43.28 a
N_2P_3	472.30 b	2.19 b	2.98 ab	41.36 b
N_3P_0	196.60 h	0.91 g	1.77 ef	33.96 de
N_3P_1	352.10 f	1.63 e	2.60 cd	38.53 c
N_3P_2	470.90 b	2.15 bc	2.92 ab	41.75 b
N_3P_3	464.40 b	2.05 cd	2.78 b	41.44 b
$LSD_{0.05}$	11.63	0.129	0.242	1.504
CV(%)	9.24	9.27	11.48	10.60

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}
P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

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

Gimakalmi seed yield per hectare affected significantly due to different nitrogen (N) treatments (Appendix VIII). The highest seed yield (1.79 t ha^{-1}) was recorded from the treatment N_2 (90 kg N ha^{-1} whereas the lowest seed yield (0.71 t ha^{-1}) was recorded from the treatment N_0 (control; no nitrogen) (Table 5). This result was in agreement with the findings of Choudhury *et al*. (2006), Sison *et al*. (2019) and Gangaiah *et al*. (2021); they reported that increasing nitrogen levels significantly increased the seed yield, up to a certain threshold level beyond which further nitrogen application did not have a significant effect on seed yield.

Application of different levels of phosphorus (P) gave significant effect on seed yield per hectare of gimakalmi (Appendix VIII). Results exhibited that the highest seed yield (1.85 t ha^{-1}) was recorded from the treatment P_2 (30 kg P ha^{-1}) whereas the lowest seed yield (0.77 t ha^{-1}) was recorded from the P_0 (control; no phosphorus) treatment (Table 5). Similar result was also observed by the findings of Abbas *et al*. (2018), Ali *et al*. (2015). Rahman *et al*. (2015) reported that increasing phosphorus levels led to increased seed yield of water spinach per ha. Islam *et al*. (2019) reported higher seed yield with higher P level up to a certain threshold level.

Seed yield per hectare of gimakalmi influenced significantly due to different treatment combinations of nitrogen (N) and phosphorus (P) (Appendix VIII). Results showed that the highest seed yield (2.32 t ha^{-1}) was recorded from the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}). The lowest seed yield (0.52 t ha^{-1}) was recorded from the treatment combination of N_0P_0 (control treatment) that was statistically similar to the treatment combination of N_0P_1 (Table 5). Supported result was also observed by Rahman *et al*. (2020) and Nwankwo and Ogbodo (2017) who found that the combination of nitrogen and phosphorus significantly increased the growth and seed yield of water spinach which was supported by Datta *et al*. (2018) and Sarwar *et al*. (2018).

4.3.3 Stover yield ha^{-1}

Different nitrogen (N) treatments showed significant variation on stover yield ha^{-1} of gimakalmi (Appendix VIII). The highest stover yield (2.62 t ha^{-1}) was recorded from the treatment N_2 (90 kg N ha^{-1}) whereas the lowest stover yield (1.42 t ha^{-1}) was recorded from the treatment N_0 (control; no nitrogen) (Table 5).

Application of different levels of phosphorus (P) had significant influence on stover yield ha^{-1} of gimakalmi (Appendix VIII). The highest stover yield (2.61 t ha^{-1}) was recorded from the treatment P_2 (30 kg P ha^{-1}) followed by the treatment P_3 (40 kg P ha^{-1}) whereas the lowest stover yield (1.55 t ha^{-1}) was recorded from the treatment P_0 (control; no phosphorus) (Table 5).

Different combinations of nitrogen (N) and phosphorus (P) showed significant variation on stover yield ha^{-1} of gimakalmi (Appendix VIII). Treatment combinations of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) showed the highest stover yield (3.04 t ha^{-1}) which was statistically similar to the treatment combination of N_2P_3 and N_3P_2. The lowest stover yield (1.16 t ha^{-1}) was recorded from the treatment combination of N_0P_0 (control treatment) that was statistically similar to the treatment combination of N_0P_1 (Table 5).

4.3.4 Harvest index

Different treatments of nitrogen (N) showed significant variation on harvest index of gimakalmi (Appendix VIII). The highest harvest index (39.53%) was recorded from the treatment N_2 (90 kg N ha^{-1}) which differed significantly with other treatments whereas the lowest harvest index (33.03%) was recorded from the treatment N_0 (control; no nitrogen) (Table 5).

Application of different phosphorus (P) levels showed significant influence on harvest index of gimakalmi (Appendix VIII). The highest harvest index (38.93%) was recorded from the treatment P_2 (30 kg P ha^{-1}) which was significantly different with other treatments whereas the lowest harvest index (33.04%) was recorded from the treatment P_0 (control; no phosphorus) that was significantly different to other treatments (Table 5).

Different combination of nitrogen (N) and phosphorus (P) showed significant variation on harvest index of gimakalmi (Appendix VIII). The treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) showed the highest harvest index (43.28%) which differed significantly with other treatment combinations. The lowest harvest index (30.95%) was recorded from the treatment combination of N_0P_0 (control treatment) which differed significantly to other treatment combinations (Table 5).

4.4 Seed quality parameters

4.4.1 Germination

Non-significant variation was observed on seed germination of gimakalmi seeds as influenced by different nitrogen (N) treatments (Appendix IX). The highest seed germination (85.75%) was given by the treatment N_2 (90 kg N ha^{-1}) which was significantly different from other treatments followed by N_3 (120 kg N ha^{-1}) whereas the lowest seed germination (80.90%) was found from seeds which was obtained from N_0 (control; no nitrogen) treatment (Table 6). Similar result was also observed by Islam *et al.* (2019) who found significant effect on germination percentage of produced water spinach seeds with nitrogen application.

Seeds of gimakalmi obtained from different phosphorus (P) levels showed significant variation on seed germination (Appendix IX). The highest seed germination (85.18%) was recorded from the seeds obtained from P_2 (30 kg P ha^{-1}) treatment which was statistically same with P_3 (40 kg P ha^{-1}) treatment whereas seeds obtained from P_0 (control; no phosphorus) treatment gave the lowest seed germination (81.40%) (Table 6). Islam *et al.* (2019) also found similar result with the present study and observed significant variation on on germination percentage of produced water spinach seeds among different phosphorus treatments.

Gimakalmi seeds obtained from the treatment combinations of different nitrogen (N) and phosphorus (P) showed significant variation on seed germination (Appendix IX). Seeds obtained from N_2P_2 treatment combination showed highest seed germination (88.20%) which was statistically identical to the treatment combination of N_2P_3. Reversely, seeds obtained from the treatment combination of N_0P_0 showed the lowest seed germination (78.40%) that was statistically similar to N_0P_1, N_1P_0, N_0P_2 and N_0P_3 (Table 6).

4.4.2 Shoot length

Shoot length after germination at 12 days, different nitrogen (N) treatments showed significant variation (Appendix IX). The highest shoot length (7.53 cm) was given by the treatment N_2 (90 kg N ha^{-1}) which was statistically identical to the treatment N_3 (120 kg N ha^{-1}) whereas seeds obtained from N_0 (control; no nitrogen) treatment showed the lowest shoot length (6.05 cm) (Table 6).

Shoot length after 12 days of germination, different treatments of phosphorus (P) showed significant variation (Appendix IX). Seeds obtained from P_2 (30 kg P ha^{-1}) treatment gave the highest shoot length (7.50 cm) that was statistically identical to P_3 (40 kg P ha^{-1}) whereas seeds of P_0 (control; no phosphorus) treatment gave the lowest shoot length (6.25 cm) (Table 6).

Different treatment combinations of nitrogen (N) and phosphorus (P), shoot length at 12 days after germination of seeds showed significant variation (Appendix IX). Seeds obtained from the treatment combination of N_2P_2 gave the highest shoot length (8.14 cm) which was statistically similar to N_2P_3, N_3P_2 and N_3P_3 whereas seeds obtained from N_0P_0 gave the lowest shoot length (5.78 cm) which was statistically similar to the treatment combinations of N_0P_1 and N_1P_0 (Table 6).

Table 6. Seed quality parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Treatments	Seed quality parameters			
	Germination (%)	Shoot length (cm)	Root length (cm)	Seed vigour index
Effect of nitrogen				
N_0	80.90 d	6.05 c	5.45 c	931.20 d
N_1	83.43 c	7.04 b	6.72 b	1149.00 c
N_2	85.75 a	7.53 a	7.23 a	1269.00 a
N_3	84.60 b	7.34 a	7.04 a	1218.00 b
$LSD_{0.05}$	0.967	0.204	0.258	23.86
CV(%)	5.88	4.72	5.94	8.73
Effect of phosphorus				
P_0	81.40 c	6.25 c	5.76 c	978.80 d
P_1	83.18 b	6.83 b	6.30 b	1093.00 c
P_2	85.18 a	7.51 a	7.27 a	1261.00 a
P_3	84.93 a	7.37 a	7.13 a	1234.00 b
$LSD_{0.05}$	0.871	0.242	0.258	21.47
CV(%)	5.88	4.72	5.94	8.73
Combined effect of nitrogen and phosphorus				
N_0P_0	78.40 j	5.78 j	4.88 j	835.70 n
N_0P_1	81.30 i	5.94 ij	5.24 i	908.90 m
N_0P_2	82.20 ghi	6.36 gh	5.90 gh	1008.00 k
N_0P_3	81.70 hi	6.12 hi	5.78 h	972.20 l
N_1P_0	81.50 i	6.04 ij	5.63 h	951.10 l
N_1P_1	83.50 def	7.00 e	6.50 ef	1127.00 h
N_1P_2	84.00 cde	7.63 bc	7.52 cd	1273.00 d
N_1P_3	84.70 c	7.48 cd	7.24 d	1247.00 e
N_2P_0	83.10 efg	6.72 f	6.32 f	1084.00 i
N_2P_1	84.20 cd	7.24 de	6.80 e	1182.00 f
N_2P_2	88.20 a	8.14 a	7.93 a	1417.00 a
N_2P_3	87.50 a	8.02 a	7.88 ab	1391.00 b
N_3P_0	82.60 fgh	6.45 fg	6.20 fg	1045.00 j
N_3P_1	83.70 de	7.12 e	6.64 e	1152.00 g
N_3P_2	86.30 b	7.90 ab	7.72 abc	1348.00 c
N_3P_3	85.80 b	7.87 ab	7.60 bc	1327.00 c
$LSD_{0.05}$	0.922	0.274	0.3029	22.79
CV(%)	5.88	4.72	5.94	8.73

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

N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}

P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}

4.4.3 Root length

Seeds of gimakalmi produced from different nitrogen (N) treatments showed significant variation on root length at 12 days after seed germination (Appendix IX). The highest root length (7.23 cm) was given by the seeds obtained from N_2 (90 kg N ha^{-1}) treatment which was statistically identical to the treatment N_3 (120 kg N ha^{-1}) whereas the seeds obtained from N_0 (control; no nitrogen) treatment showed the lowest root length (5.45 cm) (Table 6).

Root length at 12 days after germination of seed obtained from different treatments of phosphorus (P) levels showed significant variation (Appendix IX). Seeds obtained from P_2 (30 kg P ha^{-1}) treatment gave the highest root length (7.27 cm) that was significantly same to P_3 (40 kg P ha^{-1}) treatment whereas seeds of P_0 (control; no phosphorus) treatment gave the lowest root length (5.76 cm) that was significantly different to other treatments (Table 6).

Root length of 12 days after germination of seeds that were produced by different treatment combinations of nitrogen (N) and phosphorus (P) levels (Appendix IX). Seeds obtained from the treatment combination of N_2P_2 gave the highest root length (7.93 cm) which was significantly similar to N_2P_3 and N_3P_2. On the other hand, seeds obtained from the treatment combination of N_0P_0 gave the lowest root length (4.88 cm) which was significantly different from other treatment combinations (Table 6).

4.4.4 Seed vigor index

Seed vigour index of produced seeds of the present study was affected significantly due to different nitrogen (N) treatments (Appendix IX). Results indicated that the highest seed vigour index (1269.00) was given by the treatment N_2 (90 kg N ha^{-1}) followed by N_3 (120 kg N ha^{-1}) whereas the seeds of treatment N_0 (control; no nitrogen) showed the lowest seed vigour index (931.20) (Table 6).

Under the present study, N_2 (90 kg N ha^{-1}) gave the maximum vigor index compared to N_1 (60 kg N ha^{-1}), N_3 (120 kg N ha^{-1}) and N_0 (control), which indicated that N_2 (90 kg N ha^{-1}) might be the optimum dose for quality gimakalmi seed production.

Different levels of phosphorus (P) showed significant variation on seed vigour index that were produced from the present experiment (Appendix IX). The highest seed vigour index (1261.00) was recorded from the treatment P_2 (30 kg P ha^{-1}) that was followed by P_3 (40 kg P ha^{-1}) treatment whereas seeds obtained from P_0 (control; no phosphorus) treatment gave the lowest seed vigour index (978.80) (Table 6). Under the present study, P_2 (30 kg P ha^{-1}) showed the maximum vigor index of gimakalmi seeds compared to P_1 (20 kg P ha^{-1}), P_3 (40 kg P ha^{-1}) and P_0 (control), which indicated that P_2 (30 kg P ha^{-1}) might be the optimum dose of phosphorus for quality gimakalmi seed production.

Significant influence was observed on seed vigour index of produced seeds by combined effect of nitrogen (N) and phosphorus (P) (Appendix IX). The seeds obtained from the treatment combination of N_2P_2 registered the highest seed vigour index (1417.00) which was significantly different from other treatment combinations followed by N_2P_3. Reversely, seeds from the treatment combination of N_0P_0 showed the lowest seed vigour index (835.70) which was significantly different from other treatment combinations (Table 6).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out during the period of September 2021 to March 2022 at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to study the effect of nitrogen and phosphorus on growth and seed yield of gimakalmi. The experiment consisted of two factors: Factor A: four nitrogen levels *viz*. N_0 = Control (no nitrogen), N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1} and Factor B: four phosphorus levels *viz*. P_0 = Control (no phosphorus), P_1 = 20 kg P ha^{-1}, P_2 = 30 kg P ha^{-1}, P_3 = 40 kg P ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. Data on different growth, yield contributing parameters, yield and seed quality of gimakalmi were recorded and analyzed statistically.

Regarding growth parameters, different levels of nitrogen (N) applied to gimakalmi, showed significant variation on different growth parameters at different growth stages. At 90 DAS, the treatment N_3 (120 kg N ha^{-1}) showed the maximum plant height (38.47 cm) and number of leaves $plant^{-1}$ (156.75) while the treatment N_2 (90 kg N ha^{-1}) gave the maximum number of branches $plant^{-1}$ (20.16) whereas N_0 (control; no nitrogen) treatment showed the minimum plant height (25.92 cm), number of leaves $plant^{-1}$ (131.20) and number of branches $plant^{-1}$ (14.91). Regarding yield contributing parameters and yield, significant variation was found among the N treatments. The highest number of pods $plant^{-1}$ (676.40), seed weight $plant^{-1}$ (16.06 g), 1000 seed weight (5.93 g), seed yield $plot^{-1}$ (387.50 g), seed yield ha^{-1} (1.79 t), stover yield ha^{-1} (2.62 t) and harvest index (39.53%) were recorded from the treatment N_2 (90 kg N ha^{-1}) whereas the lowest number of pods $plant^{-1}$ (268.30), seed weight $plant^{-1}$ (6.37 g), 1000 seed weight (5.41 g), seed yield $plot^{-1}$ (152.80 g), seed yield ha^{-1} (0.71 t), stover yield ha^{-1} (1.42 t) and harvest index (33.03%) were recorded from the treatment N_0 (control; no nitrogen). In case of seed quality parameters, N treatments had significant variation and the treatment N_2 (90 kg N ha^{-1}) registered the highest seed germination (85.75%), shoot length (7.53 cm), root length (7.23 cm) and seed vigor index (1269.00) at 12 days of germination test whereas N_0 (control; no nitrogen) treatment gave the lowest seed germination (80.90%), shoot length (6.05 cm), root length (5.45 cm) and seed vigor index (931.20) at 12 days of germination test.

Different phosphorus (P) treatments showed significant variation on different growth parameters of gimakalmi. At 90 DAS, the treatment P_3 (40 kg P ha^{-1}) showed the maximum plant height (35.15 cm) and number of leaves $plant^{-1}$ (151.15) while the treatment P_2 (30 kg P ha^{-1}) gave the maximum number of branches $plant^{-1}$ (19.69) whereas P_0 (control; no phosphorus) treatment showed the minimum plant height (29.47 cm), number of leaves $plant^{-1}$ (137.90) and number of branches $plant^{-1}$ (15.69). Regarding yield contributing parameters and yield, different P levels showed significant variation. The highest number of pods $plant^{-1}$ (679.20), seed weight $plant^{-1}$ (16.06 g), 1000 seed weight (5.93 g), seed yield $plot^{-1}$ (387.50 g), seed yield ha^{-1} (1.79 t), stover yield ha^{-1} (2.61 t) and harvest index (68.93%) were recorded from the treatment P_2 (30 kg P ha^{-1}) whereas the lowest number of pods $plant^{-1}$ (319.90), seed weight $plant^{-1}$ (6.95 g), 1000 seed weight (5.44 g), seed yield $plot^{-1}$ (166.90 g), seed yield ha^{-1} (0.77 t), stover yield ha^{-1} (1.55 t) and harvest index (33.05%) were recorded from the treatment P_0 (control; no phosphorus). In case of seed quality parameters, N treatments had significant variation and the treatment P_2 (30 kg P ha^{-1}) registered the highest seed germination (85.18%), shoot length (7.51 cm), root length (7.27 cm) and seed vigor index (1261.00) at 12 days of germination test whereas P_0 (control; no phosphorus) treatment gave the lowest seed germination (81.40%), shoot length (6.25 cm), root length (5.76 cm) and seed vigor index (978.80) at 12 days of germination test.

Treatment combination of nitrogen (N) and phosphorus (P) showed significant variation on the growth parameters of gimakalmi at different growth stages. At 30, 60 and 90 DAS, the maximum plant height at 90 DAS (41.44 cm) and number of leaves plant^{-1} (165.30) were recorded from the treatment combination of N_3P_3 while the the maximum number of branches plant^{-1} (22.40) was found from N_2P_2 whereas the minimum plant height (22.04 cm), number of leaves plant^{-1} (122.90) and number of branches plant^{-1} (14.20) at 90 DAS was recorded from the treatment combination of N_0P_0. Regarding yield contributing parameters and yield, significant variation was found among the treatment combination of N and P. The highest number of pods plant^{-1} (835.90), seed weight plant^{-1} (20.88 g), 1000 seed weight (6.24 g), seed yield plot^{-1} (501.10 g), seed yield ha^{-1} (2.32 t), stover yield ha^{-1} (3.04 t) and harvest index (43.28%) were recorded from the treatment combination of N_2P_2 whereas the lowest number of pods plant^{-1} (220.80), seed weight plant^{-1} (4.68 g), 1000 seed weight (5.30 g), seed yield plot^{-1} (112.30 g), seed yield ha^{-1} (0.52 t), stover yield ha^{-1} (1.16 t) and harvest index (30.95%) were recorded from the treatment combination of N_0P_0. In case of seed quality parameters, N and P treatment combinations had significant variation. At 12 days of germination test, the treatment combination of N_2P_2 showed the highest seed germination (88.20%), shoot length (8.14 cm), root length (7.93 cm) and seed vigor index (1417.00) whereas N_0P_0 treatment combination gave the lowest seed germination (78.40%), shoot length (5.78 cm), root length (4.88 cm) and seed vigor index (835.70).

Conclusion

From the present study, the following conclusion may be drawn –

1. Among four nitrogen (N) treatments, the results on the most of the parameters of gimakalmi showed significant variation, and N_2 (90 kg N ha^{-1}) treatment showed the best performance regarding yield contributing parameters, yield and seed quality.
2. Regarding of phosphorus application, the treatment P_2 (30 kg P ha^{-1}) showed best crop performance, highest seed yield and better quality seeds.

3. The treatment N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) gave the best results in respect of maximum seed yield and better seed quality.

So, the treatment combination of N_2P_2 (90 kg N ha^{-1} + 30 kg P ha^{-1}) can be considered as best combination for higher seed yield and also quality seeds compared to other treatment combinations.

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APPENDICES

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

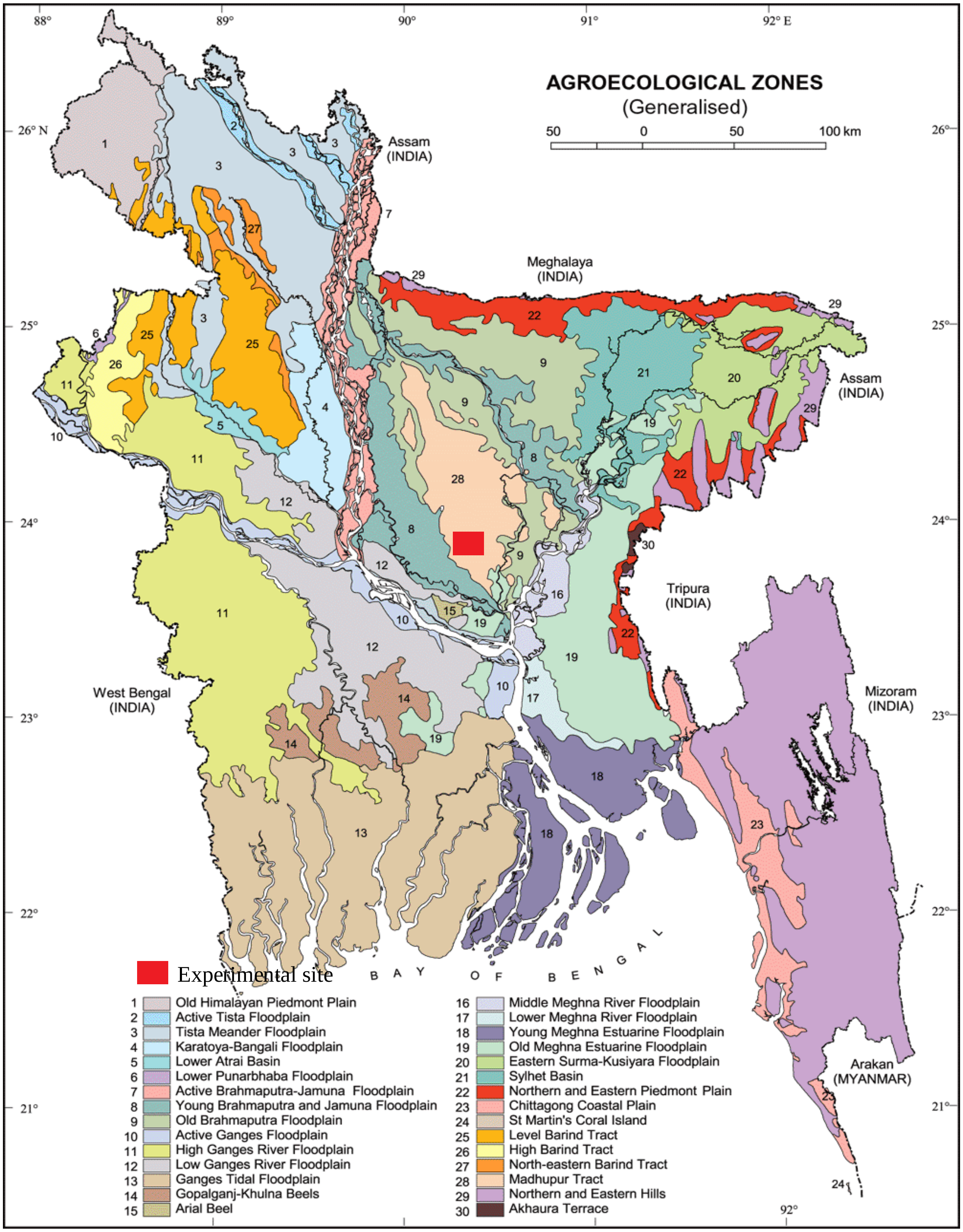

Fig. 8. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from August 2021 to December 2021

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2021	August	31.00	25.60	28.30	80.00	348
2021	September	30.8	21.80	26.30	71.50	78.52
2021	October	30.42	16.24	23.33	68.48	52.60
2021	November	28.60	8.52	18.56	56.75	14.40
2021	December	25.50	6.70	16.10	54.80	0.0

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

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

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

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

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Plant height of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		30 DAS	60 DAS	90 DAS
Replication	2	1.042	2.311	4.036
Factor A	3	15.76*	52.72*	743.56*
Factor B	3	11.54*	37.83*	284.71*
AB	9	6.28**	9.69**	23.62*
Error	30	0.736	1.014	0.384

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

Appendix V. Number of leaves plant^{-1} of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		30 DAS	60 DAS	90 DAS
Replication	2	2.103	3.072	5.117
Factor A	3	21.87*	102.39*	121.74*
Factor B	3	12.45*	84.28*	204.38*
AB	9	6.92**	21.47*	52.94*
Error	30	0.371	0.773	2.804

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

Appendix VI. Number of branches plant^{-1} of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}		
		30 DAS	60 DAS	90 DAS
Replication	2	0.201	0.524	1.036
Factor A	3	6.32*	5.22*	11.63*
Factor B	3	4.17*	7.36*	8.21*
AB	9	1.89**	3.14*	3.78*
Error	30	0.011	0.107	0.211

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

Appendix VII. Yield contributing parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters		
		Number of pods $plant^{-1}$	Seed weight $plant^{-1}$ (g)	1000 seed weight (g)
Replication	2	4.272	2.511	0.364
Factor A	3	530.74*	44.27*	1.403**
Factor B	3	324.56*	18.34*	0.711**
AB	9	89.94*	10.18**	0.248**
Error	30	27.87	0.107	0.003

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

Appendix VIII. Yield parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Seed yield $plot^{-1}$ (g)	Seed yield ha^{-1} (t)	Stover yield ha^{-1} (t)	Harvest index (%)
Replication	2	3.971	0.073	0.094	0.106
Factor A	3	326.43*	2.471**	3.114*	8.712*
Factor B	3	174.25*	0.942**	1.078**	11.47*
AB	9	72.55*	0.671**	0.594**	3.86**
Error	30	16.21	0.002	0.007	0.271

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

Appendix IX. Seed quality parameters of gimakalmi as influenced by different doses of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Germination (%)	Shoot length (cm)	Root length (cm)	Seed vigour index
Replication	2	1.043	0.271	0.109	1.318
Factor A	3	204.72*	3.440*	2.148**	1447.88*
Factor B	3	91.76*	5.186*	3.307*	806.97*
AB	9	29.47*	1.049**	0.894**	104.54*
Error	30	0.102	0.009	0.011	62.25

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