GROWTH AND FLOWERING OF GOLDEN ROD (*Solidago* sp.) INFLUENCED BY POPULATION DENSITY AND PHOSPHORUS

FARZANA ISLAM

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2015

GROWTH AND FLOWERING OF GOLDEN ROD (*Solidago* sp.) INFLUENCED BY POPULATION DENSITY AND PHOSPHORUS

BY

FARZANA ISLAM

REG. NO. : 09-03422

A Thesis
Submitted to the Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY-JUNE, 2015

Approved by

Prof. Md. Ruhul Amin Department of Horticulture SAU, Dhaka **Supervisor**	**Prof. Abul Faiz Md. Jamal Uddin (Ph.D.)** Department of Horticulture SAU, Dhaka **Co-Supervisor**

Dr. Tahmina Mostarin
Chairman
Examination Committee

Department of Horticulture

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No.: Dated:

CERTIFICATE

This is to certify that the thesis entitled **"GROWTH AND FLOWERING OF GOLDEN ROD (*Solidago* sp.) INFLUENCED BY POPULATION DENSITY AND PHOSPHORUS"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **FARZANA ISLAM,** Registration No. **09-03422** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2015
Dhaka, Bangladesh

Prof. Md. Ruhul Amin
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

All praises to the ***"Almighty Allah"*** *who enable me to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Horticulture.*

I feel much pleasure to express my gratefulness, sincere appreciation and heartfelt liability to my venerable research supervisor ***Professor Md. Ruhul Amin****, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period.*

I also express my gratitude and thankfulness to reverend co-supervisor ***Professor Abul Faiz Md. Jamal Uddin, Ph.D.*** *Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for his heartiest co-operation and supports throughout the study period.*

It is also an enormous pleasure for the author to express her cordial appreciation and thanks to the Chairman ***Assoc. Prof. Dr. Tahmina Mostarin,*** *Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207 for her encouragement and co-operation in various stages towards completion of this research work.*

The Author wishes to express her gratitude and heartfelt thanks to her ***honorable teachers*** *of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207 for their valuable teaching, indirect advice and enormous inspiration throughout the research work.*

The author deeply acknowledges the profound dedication to her beloved ***Father, Mother, Sister and Brother*** *for their moral support, steadfast encouragement and continuous prayer in all phases of academic pursuit from the beginning to the completion of study successfully.*

Finally, the author is deeply indebted to her friends and well-wishers for their kind help, constant inspiration, co-operation and moral support which can never be forgotten.

The Author

GROWTH AND FLOWERING OF GOLDEN ROD (*Solidago* sp.) INFLUENCED BY POPULATION DENSITY AND PHOSPHORUS

BY

FARZANA ISLAM

ABSTRACT

The study was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from May 2014 to October 2014. The experiment consisted of two factors. Factor A: Three levels of population density: D_1 - 125000, D_2 -83333, D_3 - 62500 plants ha^{-1} and Factor B: four levels of phosphorus: P_0 - Control (0 kg), P_1 - 100 kg, P_2 -125 kg and P_3 - 150 kg P_2O_5, respectively. The experiment was laid out in Randomized Complete Block Design with three replications. Population density and phosphorus levels showed significant variations with most of the parameters. In the case of population density the highest no. of spike (659896 ha^{-1}) was recorded from D_1 and the lowest no. of spike (302240 ha^{-1}) from D_3. For phosphorus, the highest no. of spike (515972 ha^{-1}) was recorded from P_2 and the lowest no. of spike (372014 ha^{-1}) from P_0. For combine effect the highest no. of spike (752708 ha^{-1}) was from D_1P_2 and the lowest (248958 ha^{-1}) from D_3P_0. The highest benefit cost ratio (2.49) was noted from D_1P_2 and the lowest (1.08) from D_3P_0. So, the use of higher population density (125000 plants ha^{-1}) with 125 kg P_2O_5 ha^{-1} was the best for growth and flowering of golden rod.

LIST OF CONTENTS

LIST OF CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

@	=	At the rate of
AEZ	=	Agro-ecological Zone
Agric.	=	Agriculture
Agril.	=	Agricultural
ANOVA	=	Analysis of variance
BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
^0C	=	Degree Centigrade
CV%	=	Percent of Co-efficient of variation
DAT	=	Days after transplanting
DMRT	=	Duncan’s Multiple Range Test
et al.	=	and others
Kg	=	Kilogram
Kg ha^{-1}	=	Kilogram per hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t ha^{-1}	=	ton per hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Golden rod (*Solidago sp.*) is a plant from Asteraceae family, which includes about 122 species worldwide (Lopez *et al.,* 2011). All species are herbaceous, hardy, perennials ranging from 2 cm to 2.5 m tall. This usually have small heads with yellow pistillate ray florets and perfect disc florets aggregated into flat-topped, wand-shaped or secund-conical inflorescences. The phyllaries are generally lanceolate to ovate or oblong, present in 2-4 graduated series, and have a translucent midrib (Semple *et al.,* 2015). It has large, yellow, attractive panicles, flowers for several months in a year. *Solidago* is native to Mexico, Eastern and Southern USA, and Canada, between the latitudes 26°N and 65°N (Weber, 2000). Worldwide, it has naturalized in Europe, New Zealand, Australia, and parts of Asia to an alien plant (Weber, 2001).

It is commonly used for cut flower and one of the essential filler flower with long vase life for flower arrangement. The spectacular flowers have yellow color and the most popular florist's flower. They are suitable for planting in beds, borders, rock garden and also used as indoor decoration and in bouquets along with other flowers. It is an excellent dry flower. In north-eastern Croatia, it is still valued by beekeepers (Stefanic *et al*., 2003). It is an important source of both nectar and pollen for bees, butterflies, and some wasps. It was traditionally used to make a beautiful yellow dye. It also permitted for use as an herbal medicine ingredient in several countries (Wu *et al*., 2008). Extracts from the dry shoots, harvested at the beginning of flowering, and it has been used in European phytotherapy for centuries as a urological and antiphlogistical remedy (Apati *et al*., 2003). An ethyl acetate extract from the roots, inhibited the growth of human gastric adenocarcinoma cells (Lu *et al*., 2006). Beside those, it's easy cultivation, adaptability to varying soil and climatic conditions and excellent keeping quality, so there is a great scope for cultivation of golden rod in Bangladesh.

Population density is an important factor in contributing quality of ornamental crops. A uniform distribution of plants per unit area is a prerequisite for yield stability (Diepenbrock, 2000). It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. But the efficiency of pollen transfer of wind-pollinated plants decrease rapidly with increasing distance between plants (Culley *et al*. 2002).Wider spacing has substantial evidence that isolated plants which may increase their reproductive effort by producing more and larger flowers (Mustajarvi *et al*., 2001). But it decreases the total number of plants as well as total yield. Crop yield may be increased up to 25% by using optimum spacing (Bansal *et al*., 1995). Another studies indicated that optimum population density provided favorable conditions to flourish the crop for higher flower yield (Karuppaiah and Krishna, 2005).

Phosphorus is one of the important essential macro elements for the normal growth and development and key input for increasing crop yield (Dastan *et al.*, 2012). It's requirement vary depending upon the nutrient content of soil (Bose and Som, 1986). It allows plant to perform photosynthesis or convert light into energy. It is required in sufficient quality to attain better growth and promote flowering (Pandey and Mishra, 2005). Phosphorus stimulates early root growth and development, encourages more active tillering and promotes early flowering (Khandaker, 2003). It has significant effect on spike production and floret quality (Singh *et al.,* 2005). It is involved in biochemical synthesis of sugar, starch and polysaccharides, nucleic acid formation, cell elongation and transfer of heredity character (Rahman *et al*., 2011). It contributes in the extension of postharvest life of cut flowers. Absorption of phosphorus from the soil through luxury consumption, increasing the tissue content with enhancing smooth biomass accumulation for plant (Santos *et al.,* 2004).

Golden rod is a new member in floriculture industry of our country. Scientific finding about its cultivation relating to fertilization and optimum population density for successful production is scanty in Bangladesh. But now a days there is a great demand of its panicles in local market as filler flower in bouquet preparation, pot flower arrangements and for other uses. Flower producers and florists are interested to increase its production and use. Considering the present situation and above facts the present investigation was undertaken with the following objectives-

1. To find out optimum population density of golden rod.
2. To find out optimum dose of phosphorus for golden rod.
3. To determine the interaction effect of population density and phosphorus for cultivation of golden rod in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

Golden rod is newly introduced important filler flower in our country. It is a gross feeder and requires judicial management regarding population density and nutrient status. The required population density and nutrients for optimum growth and development of a crop depends upon the climatic and soil conditions. A few reports are available regarding the requirement of population density and fertilizers for growth and flowering of it. Very limited studies have been done on this crop under the agro-ecological condition of Bangladesh in respect of population density and phosphorus requirement. A brief review of these pertinent to the present study has been given below:

2.1 Effect of population density

Amira and Sewedan (2014) observed from an experiment with population density of golden rod and results revealed that stem height, stem circumference, fresh and dry weight, total leaves area plant^{-1}, inflorescence length, percentage inflorescence, length stem^{-1}, number of flowering branches, inflorescence stem plant^{-1}, flowering branches, length inflorescence^{-1}, vase life, total chlorophyll and carotene contents of leaves increased significantly by reducing planting density. While, significant delay from (120 to 125 days) in flowering occurred due to increasing planting density.

Tingare and Patil (2007) laid out a field experiment in factorial randomized block design with three spacings *viz*., 30 × 20 cm, 30 × 30 cm and 30 × 40 cm, four nitrogen levels *viz*., 0, 100, 150 and 200 kg N ha^{-1} along with four replications, showed that growth of the plant, quality of flower and yield increased with increasing levels of nitrogen. The spacing of 30 × 30 cm (28 plants/2.42 m^2) and 150 kg N ha^{-1} nitrogen application of 150 kg ha^{-1} was found optimum for the production of desirable quality and yield of flowers of golden rod.

Yadav and Tyagi (2007) carried out a study in the experimental field of College Machhra, Meerut, Uttar Pradesh, India, to determine the effect of corm size and spacing (25×20, 25×30 and 25×40 cm) on growth and flowering of gladiolus. It was observed that all the growth and flowering parameters increased with the corm size and spacing, whereas the planting of small corms advanced the sprouting of corms.

Xiao *et al.* (2006) suggested that the mean height of plants will decrease with increasing density when the population density reaches a certain value. When there is competition for light between neighbors, height growth will help individual plants avoid the shading effect of its neighbors and enable it to acquire more of the light resource.

Shiraz and Maurya (2005) conducted an experiment to find out the effects of spacing (25×10, 25×20 or 25×30 cm) and corm size on the performance of gladiolus in Sobour, Bihar, India. The widest spacing (25×30 cm) resulted in the greatest plant height (152.28 cm), number of leaves plant^{-1} (10.11), number of spikes plant^{-1} (2.53), spike length (87.31), number of florets spike^{-1} (14.75), floret diameter (9.35 cm), number of corms plant^{-1} (2.47) and diameter of new corm (6.00 cm), and the lowest number of days to first spike emergence (62.44) and number of days to first floret opening (72.89).

Sharma and Gupta (2003) conducted an experiment to find out the effects of corm size (3.1-3.5, 3.6-4.0, 4.1-4.5 and 4.6-5.0 cm) and spacing (10×40, 20×40, 30× 40 and 40×40 cm) on the growth and flowering of gladiolus were determined in a field experiment conducted in Haryana, India during 1997-99. Plant height, number of leaves plant^{-1}, spike length, number of florets spike^{-1} and number of spike plant^{-1} increased, whereas the number of days to spike emergence and blooming decreased with increasing corm size. Increasing spacing resulted in increasing values for plant height, spike length, number of florets spike^{-1} and number of spikes plant^{-1}. The number of corms plant^{-1}, corm weight and diameter, number of cormels plant^{-1} and cormel weight plant^{-1} increased with increasing corm size and plant spacing.

Bijimol and Singh (2001) conducted an experiment was by to assess the effect of spacing and nitrogen levels on flowering, flower quality and vase life of gladiolus cv. Red Beauty. Four spacing (15×30, 20×30, 25×30 and 30×30 cm) and four nitrogen rates (0, 100, 200 and 00 kg/ha) were taken. Corms planted at 25×30 cm and 200 kg N ha^{-1} significantly increased the diameter of spike, number of florets spike^{-1}, number of spikes plant^{-1} and number of spikes ha^{-1} and early emergence of spike under field conditions. Application of 200 kg N ha^{-1} also resulted in maximum length of spike and diameter of floret. However, early opening of flower was recorded with lower N rate (100 kg ha^{-1}), while length of floret with 300 kg N ha^{-1}. Spacing and N levels had significant effect on postharvest life of cut gladioli. Spacing 25×30 cm had striking effect on percent opening of florets spike^{-1}, number of open florets with drooping of minimum florets.

Singh and Sangama (2000) noted the effect of seven plant spacing, viz. 30 X 30, 30 × 20, 30 × 10, 20 × 20, 20 × 12.5, 20 × 10 and 20 × 8.5 cm, on vegetative growth, flowering and postharvest quality of cut spikes in tuberose cv. Single was investigated at Bangalore, Karnataka, India, during 1997-98. Wider spacing resulted in longer rachis and heavier individual florets. Closer spacing produced higher yield of cut flower and loose flower per plot basis. Wider and closer spacing have vice versa effect on above floral parameters. Rest of the studied parameters namely, plant height, number of leaves clump^{-1}, spike length, diameter of second floret, flowering duration under field condition and number of florets spike^{-1} and their corresponding weight and post harvest quality of cut flower were not influenced significantly by the plant densities.

Misra *et al.* (2000) conducted an experiment to determine the effect of bulb size spacing on plant growth and flowering of two tuberose (*Polianthes tuberose* L.) cultivars (Single and Double). Bulb size significantly influenced the initiation of spikes in both cultivars. The maximum days for spike initiation by smaller bulb size was 170.8 and 222.7 days for single and double cultivars, respectively. The larger bulb size produced the highest number of spikes plant^{-1} for both cultivars. With closer spacing, the plants took a longer time to produce spikes than wider spaced-plants. The number of spikes plant^{-1} was higher in wider spaced-plants. The spike length and number of florets decreased in closer spaced-plants. However, a bulb size of 2.60 - 3.00 cm at 30 × 30 cm spacing was the best for both the cultivars

Bansal *et al*. (1995) stated that spacing plays a major role in obtaining satisfactory crop with desirable quality. Spacing is also an important aspect of crop production for maximizing the yield. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand wider spacing ensures the basic requirements but decrease the total number of plants as well as total yield. Crop yield may be increased up to 25% by using optimum spacing

Mollah *et al.* (1995) studied the effect of cormel size and spacing on growth and flower and corm of gladiolus in Bangladesh. They reported that the widest spacing (15 cm ×15 cm) produced the maximum length of spike (36.34 cm), longest rachis (11.9 cm), maximum plant height (56.60 cm), maximum percentage of flowering plant (54.60), heavier corm (31.33 g) and highest number of cormels (21.87) plant^{-1}.

2.2 Effect of phosphorus

Amin *et al*. (2012) conducted a field experiment at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from April, 2009 to March, 2010 to investigate the effect phosphorus on growth, flowering and bulb yield of tuberose. The experiment consisted of Four levels of phosphorus i.e. P_0: 0, P_1: 135, P_2: 145 and P_3: 155 kg P_2O_5 ha^{-1} respectively and was laid out with Randomized Complete Block Design with three replications. Plant height, leaf breath, side shoot number $plant^{-1}$, side bulb production, bulb length, bulb diameter, bulb yield, spike length, spike diameter, rachis length, number of flower $spike^{-1}$ was increased with higher phosphorus level. Leaf production, leaf length also showed significant effect with phosphorus. Highest flower (19.3 t ha^{-1}) and bulb (24.7 t ha^{-1}) yield was recorded from P_3 and the lowest flower (9.6 t ha^{-1}) and bulb (14.5 t ha^{-1}) yield was recorded from P_0.

Patel and Desai (2010) conducted a field experiment during Rabi season on "Influence of organic manures and chemical fertilizers on growth and yield attributes as well as economics of golden rod (*Solidago canadensis* L.) cv. Local Yellow" to find out nutrient requirement for golden rod to obtain better quality panicle production. Eighteen treatment combinations consisting of two levels of organic manure M_1 (FYM 20 t ha^{-1}) and M_2 (Press mud 10 t ha^{-1}) as well as three levels of nitrogen i.e. N_1 (100 kg ha^{-1}), N_2 (150 kg ha^{-1}) and N_3 (200 kg ha^{-1}) including three levels of phosphorus i.e. P_1 (control), P_2 (25 kg ha^{-1}) and P_3 (50 kg ha^{-1}) were evaluated in factorial randomized block design with three replications. Result reveled that to obtain the highest side shoot number, the highest height of side shoot, higher profitable and better quality of panicles of golden rod it may be fertilized with press mud 10 t ha^{-1}, 200 kg N ha^{-1} and 50 kg P ha^{-1}, where half dose of nitrogen and full dose of press mud and phosphorus should be applied at the time of planting and remaining half dose of nitrogen should be applied one month after planting.

Yadav (2007) conducted an experiment to study the effect of N (0, 10 and 20 g m^{-2}) and P (0, 6 and 12 g m^{-2}) fertilizers on the growth and flowering of tuberose cv. Shringar. Plant height, number of leaves $plant^{-1}$, number of flowers $spike^{-1}$, length of spike, length of rachis, number of spike $plot^{-1}$ and weight of flower $spike^{-1}$ was remarkably increased with N and P application, alone and in combination. However, N and P fertilizers did not have any significant effect on the flower length. Plant height (35.50 cm), number of leaves $plant^{-1}$ (34.40), number of flowers (37.50) $spike^{-1}$, length of spike (49.40 cm), length of rachis (20.80 cm), number of spike $plot^{-1}$ (33.90), weight of flower (109.50 g) $spike^{-1}$ and shelf life were higher with combination of 20 g N and 12 g P $plot^{-1}$.

Chapuis-Lardy *et al.* (2006) did not find impact on total soil P but found increased concentrations of readily available inorganic P in topsoil under *S. gigantea*, possibly due to increased phosphatase activity.

Gupta *et al.* (2006) conducted field studies in Uttar Pradesh, India, during the 1998/99 and 1999-2000 cropping seasons, to determine the role of nitrogen (N) at 0, 40 and 80 g m^{-2} and phosphorus fertilizers (P) at 0, 150 and 300 g m^{-2} in 4 tuberose (*Polianthes tuberosa*) cultivars, i.e. Single, Double, Semi-double and Variegated, for reproductive growth parameters such as spike emergence, growth period of bud, total number of flowers $spike^{-1}$ and number of flowers appeared at a time $spike^{-1}$ and reported that the Variegated cultivar showed positive response with 80 g N m^{-2} and 150 and 300 g P m^{-2} applications.

Patel *et al.* (2006) investigated an experiment with tuberose to know the effect of N (100, 200, 300 and 400 kg N ha^{-1}) and P (100, 150 and 200 kg P_2O_5 ha^{-1}) on growth and yield of tuberose and reported that phosphorus was not significant on vegetative characters while floral characters such as rachis length and number of florets $spike^{-1}$ were found significant. Bulb yield in terms of clump weight was also found significant and 200 kg P_2O_5 ha^{-1} was recorded the highest values.

Sultana *et al.* (2006) carried out a field trial to observe the response of tuberose (cv. single) to different nutrient elements. Nutrients were 4 levels of nitrogen (0, 100, 200 and 300 kg ha^{-1}), 3 levels of phosphorus (0, 45 and 90 kg P ha^{-1}) and 3 levels of potassium (0, 80 and 160 kg K ha^{-1}) along with a blanket dose of 10 t ha^{-1} cow dung. The application of NPK significantly influenced the growth, flowering and flower quality of tuberose. All the parameters except plant height were the highest with 200 kg N, 45 kg P and 80 kg K ha^{-1} along with 10 t ha^{-1} cowdung.

Gusewell *et al.* (2005) failed to show a significant impact of invasion by Early golden rod (*Solidago gigantea*) on total soil phosphorus in Swiss wetlands.

Jakobs *et al.* (2004) observed that early golden rod (*Solidago gigantea*), introduced from North America as an ornamental species, has spreaded rapidly in Europe, becoming one of the most widespread alien invasive species. P has great impact on flowering of it.

Chen *et al.* (2003) found that seasonal variation of soil labile P fractions and phosphatase activity may be quite large. The possibility also exists that impacts on soil P vary throughout the year, due to phenological differences between early golden rod and native vegetation.

Sharma (1989) reported that N, P, K and Fe nutrients are limiting factors in successful growing of golden rod.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in execution of the experiment.

3.1 Experimental site

The experiment was conducted at Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from May 2014 to October 2014. The location of the site in 23.774^0 N latitude and 90.335^0 E longitudes with an elevation of 8.2 m from sea level. The experimental field was medium high land belonging to the Chhiata series of Grey Terrace Soil (AEZ-28, Madhupur Tract). The morphological characteristics of the land and the physical and chemical characteristics of the soil are presented in (Appendix II).

3.2 Climate

The experimental field was under subtropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period from May 2014 to October 2014 are presented in (Appendix I).

3.3 Soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Madhupur Tract under AEZ 28. The selected plot was medium high land and soil series was Tejgoan with a pH of 5.6. The analytical data of the soil sample collected from the experimental area was analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and details of the soil characteristics are presented in (Appendix II).

3.4 Land preparation

The land was first opened by ploughing with the help of power tiller and then it kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilth. The basal dose of manures and fertilizers were mixed into the soil during final land preparation.

3.5 Treatments of the experiment

The experiment was designed to study the effect of population density and phosphorus on growth, flowering and yield of goldenrod.

The experiment consisted of two factors, which are as follows:

3.5.1 Factor A: Population density

D_1 : 125000 plants ha^{-1}

D_2 : 83333 plants ha^{-1}

D_3 : 62500 ha^{-1}

3.5.2 Factor B: Phosphorus dose

P_0 : Control (without P_2O_5)

P_1 : 100 kg P_2O_5 ha^{-1}

P_2 : 125 kg P_2O_5 ha^{-1}

P_3 : 150 kg P_2O_5 ha^{-1}

3.5.3 Interaction effect of spacing and phosphorus

D_1P_0, D_1P_1, D_1P_2, D_1P_3, D_2P_0, D_2P_1, D_2P_2, D_2P_3, D_3P_0, D_3P_1, D_3P_2, D_3P_3

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each block was divided into 12 plots, where treatments were allotted at random. Thus, there were 36 unit plots altogether in the experiment. The size of each plot was 1.6 m × 1.2 m. The distance between blocks 0.5m and 0.5 m wide drains were made between the plots. Row to row and plant to plant distance in each plot was maintained as per treatment. The detailed lay-out is presented in Figure 1.

3.7 Planting materials

Golden rod plants were used for the present study and was collected from Godkhali, Jessore. In this research work the experimental material consisted of 624 plantlets (side shoots) as planting material.

3.8 Manures, fertilizers and their application methods

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were used as source of nitrogen, phosphorus and potassium respectively. Full dose of cow dung (5t ha^{-1}), TSP (as per treatment) and MP were incorporated during final land preparation. The total dose of Urea was applied in two equal installments. The following doses of manure and fertilizer were used for golden rod cultivation shown as tabular form:

Table 1. Dose and method of application of fertilizers in golden rod field

Fertilizer	Dose ha^{-1}	Application (%)		
		Basal	30 DAT	45 DAT
Cowdung	5 ton	100	-	-
Nitrogen (as urea)	130 kg	-	50	50
P_2O_5 (as TSP)	As per treatment	-	-	-
K_2O (as MP)	100 kg	100	-	-

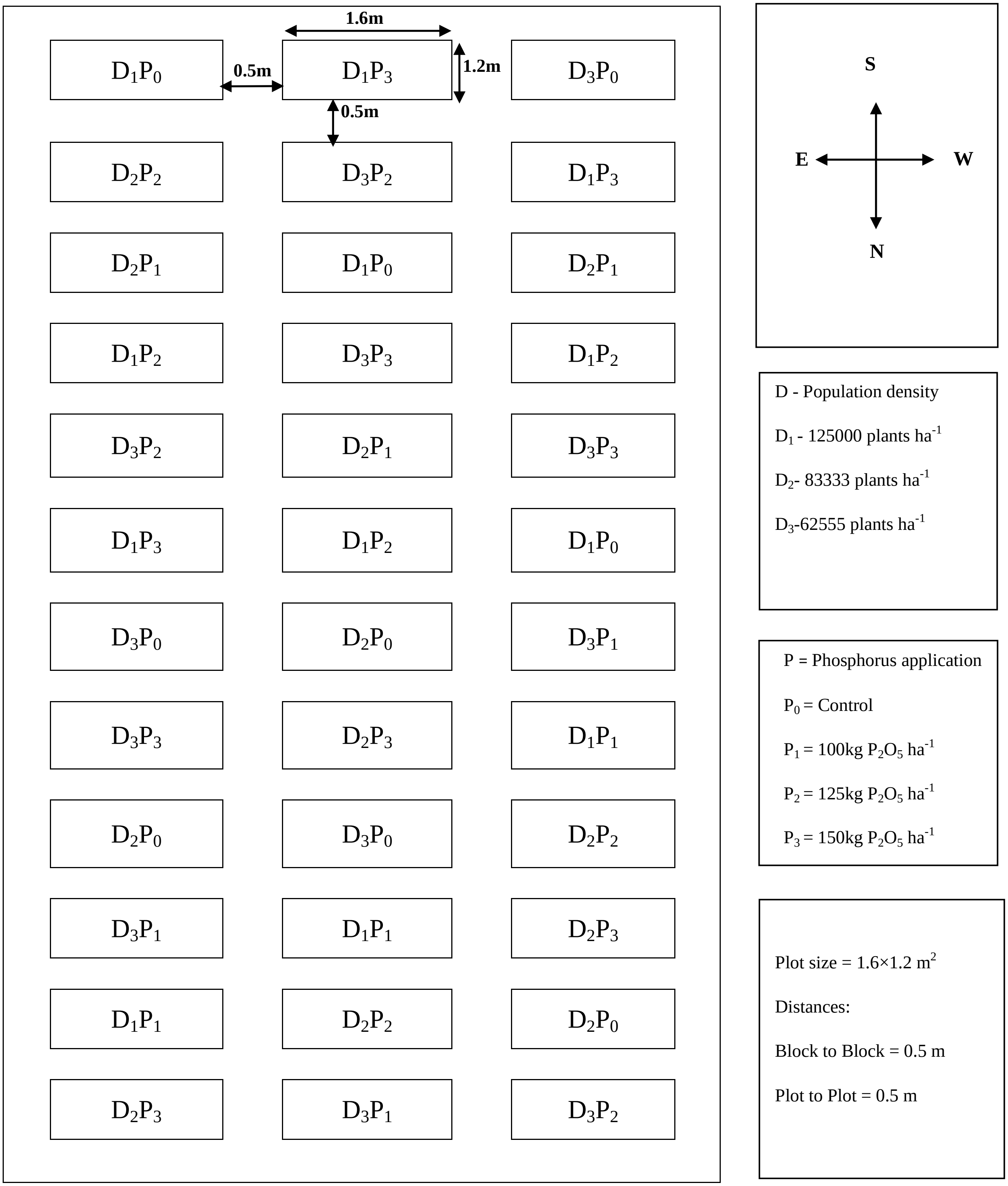


Figure 1: Layout of experiment field

3.9 Weeding and mulching

The plots were kept weed free by regular weeding. The soil was mulched frequently after irrigation by breaking the crust for easy aeration and to conserve soil moisture.

3.10 Irrigation

The experimental plots were irrigated as and when necessary during the crop period.

3.11 Selection and tagging of plants

Ten plants from each of the plots were selected randomly for recording data for different characters.

3.12 Pest management

Mole cricket, field cricket and cutworm attacks were a problem during seedling stage for goldenrod cultivation. As a preventive measure against the insect pest, Dursban 20 EC was applied @ 0.2% at 15 days interval for three times starting from 20 days after emergence of bulb.

3.13 Disease management

Dithane M-45 @ 0.2% was sprayed to check the fungal infection.

3.14 Harvesting

The spikes of goldenrod were harvested when the first floret in the rachis opened. First harvesting was done at 70 DAT.

3.15 Collection of data

3.15.1 Plant height

Plant height refers to the length of the plant from ground level upto shoot apex of the plant. It was measured three times at an interval of 20 days from 50 DAT to 90 DAT.

3.15.2 Number of leaves per plant

The number of leaves produced by mother plant was referred to the number of leaves per plant. All the leaves of ten randomly selected plants were counted and their mean was calculated. The data recorded three times at an interval of 20 days starting from 50 DAT to 90 DAT.

3.15.3 Number of side shoot

All the green shoots above the soil surface which developed from mother plant and adjoined to it were counted as side shoot. It was measured at an interval of 10 days starting from 70 days after planting (DAT) till 90 days.

3.15.4 Height of side shoot

Height of side shoot was measured from 10 selected plant and then averaged at 70 DAT and 90 DAT

3.15.5 Length of spike

Length of the flower stalk was measured from the base to the tip of the spike at 70 DAT and 90 DAT.

3.15.6 Length of rachis

Length of rachis refers to the length from the axil of first floret upto the tip of the inflorescence. Length of rachis was measured at 70DAT and 90 DAT from 10 selected plants and then averaged.

3.15.7 Number of spikelet per spike

All the spikelet of the spike was counted from 10 randomly selected plants and their mean was calculated at 70 DAT and 90 DAT.

3.15.8 Number of spike per hill

Total number of spike was counted at 70DAT and 90 DAT from 10 selected plants and average number of spike was expressed as number of spike per hill.

3.15.9 Number of spike per plot

Total number of spike was calculated from 10 randomly selected plants and it was multiplied with total number of plant in each plot of 1.92 m^2 area .

3.15.10 Spike yield per hectare by number

Total number of spike was calculated from the each plot of 1.92 m^2 area was converted to ha.

3.15.11 Shelf-life of the spike

Treatment wise shelf life was measured in days.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different level of spacing and phosphorus application on growth and flower yield of golden rod. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.17 Economic analysis

The cost of production was analyzed in order to find out the most economic combination different level of population density and phosphorus application. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. The market price of golden rod spike was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Plate 1. Seedling of golden rod in poly bag.

Plate 2. Depotting of seedling to transplant into the field .

Plate 3. Closure view of the experimental field of golden rod.

Plate 4. Distant view of the experimental field of golden rod.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth and flowering of golden rod influenced by population density and phosphorus. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices III-VIII. The results of the study have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub-headings:

4.1 Plant height

Plant height of golden rod showed statistically significant variation due to different population density at 50, 70, 90 days after transplanting (Figure 2 and Appendix III). The longest plant (69.37, 86.48 and 102.50 cm) was recorded from D_1 (125000 plants ha^{-1}) and the shortest plant (65.53, 82.48 and 99.67 cm) was found in D_3 (62500 plants ha^{-1}) followed by D_2 (83333 plants ha^{-1}) at all growth stages. The plant height was higher in D_1 because of probably there was competition for light between neighbors; height growth would help individual plants avoid the shading effect of its neighbors and enable it to acquire more of the light resources. The finding under the present study in respect of plant height was similar with the findings of Xiao *et al.* (2006).

Plant height of golden rod was highly significant for different levels of phosphorus were observed at different days after transplanting (DAT) (Figure 3 and Appendix III). Results explained that the longest plant (69.51, 89.40 and 107.10 cm) was recorded from P_1 (100 kg P_2O_5 ha^{-1}) followed by P_2 (125 kg P_2O_5 ha^{-1}) and P_3 (150 kg P_2O_5 ha^{-1}) where P_2 and P_3 showed identical. In contrary the lowest plant height (65.22, 81.18 and 97.00 cm) was achieved from P_0 (Control). In this case, plant height was higher by applying optimum amount of phosphorus. Similar results were found by Yadav (2007) and Amin *et al*. (2012).

Significant variation was found by interaction effect of population density and phosphorus on plant height of golden rod at different days after transplanting (DAT) (Table 1 and Appendix III). At 50, 70 and 90 DAT plant height was significantly influenced by different population density and different levels of phosphorus. Results explained that the longest plant (107.90 cm) was found in the combination of D_1P_1 which was statistically similar with D_1P_2 (107.8 cm) D_1P_3 (106.40 cm) and also D_2P_1 (105.60 cm) at 90 DAT. On the contrary the shortest plant (89.20 cm) was found in D_3P_0 followed by D_2P_0 (98.60 cm), D_2P_3 (97.73 cm), D_3P_1 (92.20 cm), D_3P_2 (99.00 cm) and D_3P_3 (98.13 cm) at 90 DAT.

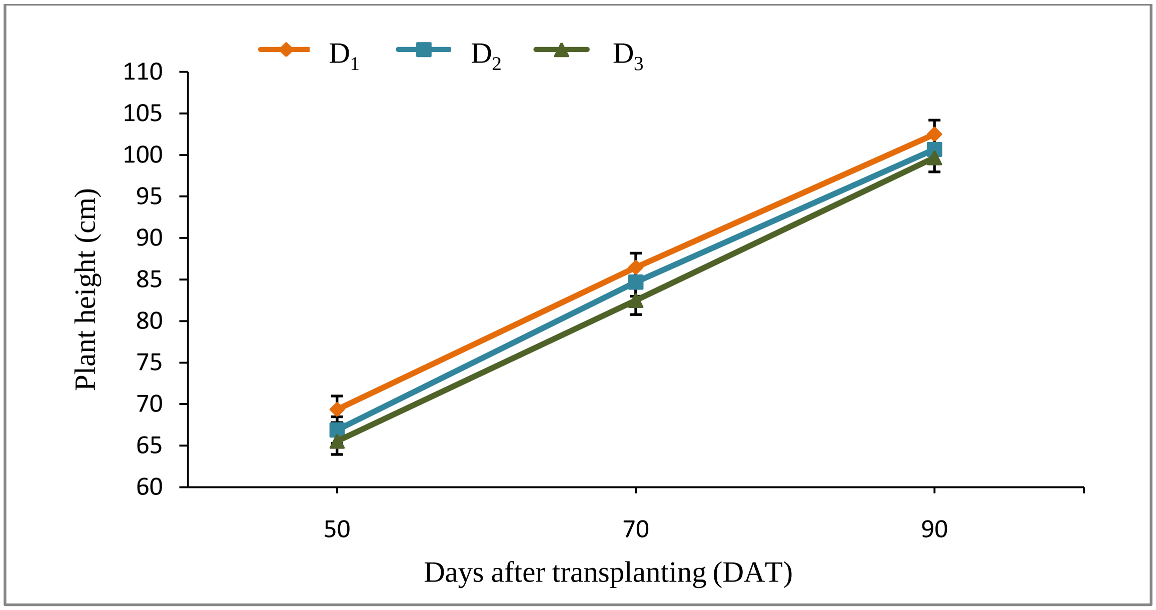


Figure 2. Effect of population density on plant height of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.61, 1.74, 1.68 at 50, 70 and 90 DAT.

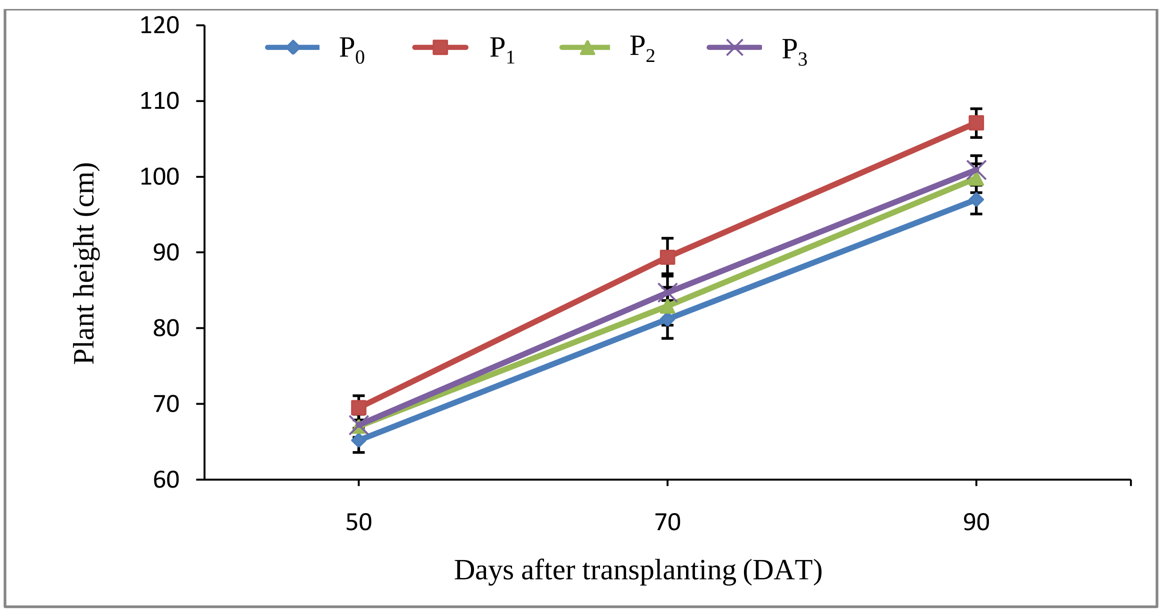


Figure 3. Effect of phosphorus on plant height of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.58, 2.46, 1.9 at 50, 70 and 90 DAT.

Table 2. Effect of population density and phosphorus on plant height of golden rod at different days after transplanting

Treatments	Plant height (cm)		
	50 DAT	70 DAT	90 DAT
D_1P_0	67.27 de	83.47 ef	103.70 c
D_1P_1	76.47 a	95.53 a	107.90 a
D_1P_2	62.27 fg	80.33 gh	107.80 ab
D_1P_3	71.47 b	86.60 d	106.40 ab
D_2P_0	70.40 bc	85.20 de	98.60 d
D_2P_1	63.53 f	83.07 f	105.60 a-c
D_2P_2	72.33 b	91.67 b	105.30 bc
D_2P_3	61.20 g	78.82 h	97.73 d
D_3P_0	58.00 h	74.87 i	89.20 f
D_3P_1	68.53 c-e	89.60 c	92.20 e
D_3P_2	66.60 e	82.13 fg	99.00 d
D_3P_3	69.00 cd	83.33 ef	98.13 d
$LSD_{0.05}$	2.161	1.877	2.377
CV (%)	8.623	7.568	9.248

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.2 Number of leaves per plant

The variation on number of leaves per plant under different population density was found statistically significant at different days after transplanting (DAT) (Figure 4 and Appendix IV). Results showed that the maximum number of leaves of golden rod (66.65, 81.64 and 97.31) at 50, 70 and 90 DAT respectively was recorded from D_3 (62500 plants ha^{-1}) followed by D_2 (83333 plants ha^{-1}). Again, the minimum number of leaves $plant^{-1}$ (60.95, 75.75 and 91.50) was observed in D_1 (125000 plants ha^{-1}). This result was obtained because when population density was lower, plants got better micro environment for leaf proliferation. So, wider spacing showed increased number of leaves per plant. Similar results were found from Amira and Sewedan (2014) and Shiraz and Maurya (2005).

There was highly significant variation for different levels of phosphorus on number of leaves per plant at different days after transplanting (DAT) (Figure 5 and Appendix IV). In this experiment the maximum number of leaves per plant (67.64, 83.20 and 98.70) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_1 (100 kg P_2O_5 ha^{-1}) and P_3 (125 kg P_2O_5 ha^{-1}) which are identical. Another way the minimum number of leaves per plant (59.33, 74.43 and 90.39) were achieved from P_0 (Control). This was obtained due to optimum dose necessary for satisfactory production of leaf number. Similar results were found from Yadav (2007).

Significant variation was found by the interaction effect of population density and phosphorus on number of leaves per plant at different days after transplanting (DAT) (Table 2 and Appendix IV). The maximum number of leaves per plant (107.2) was found in D_3P_2 followed by D_2P_2 (103.8) at 90 DAT. The results also obtained from the combined effect of D_1P_1 (99.60), D_1P_2 (99.20) and D_2P_1 (100.2) gave significantly higher number of leaves per plant but lower than D_3P_2 at all growth stages. On the contrary, the minimum number of leaves per plant (79.53) was found in D_1P_0 followed by D_2P_0 (89.30), D_1P_3 (92.43), D_2P_3 (91.00), D_3P_0 (89.40), D_3P_1(93.67) and D_3P_3(93.20) at 90 DAT.

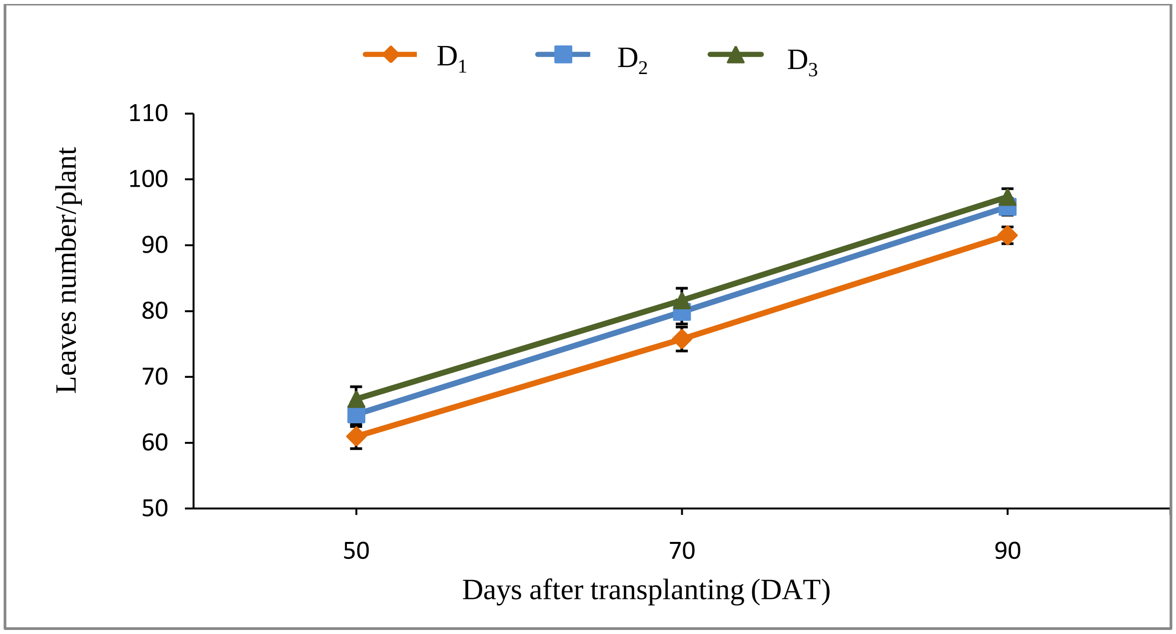


Figure 4. Effect of population density on number of leaves of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.85, 1.82, 1.27 at 50, 70 and 90 DAT.

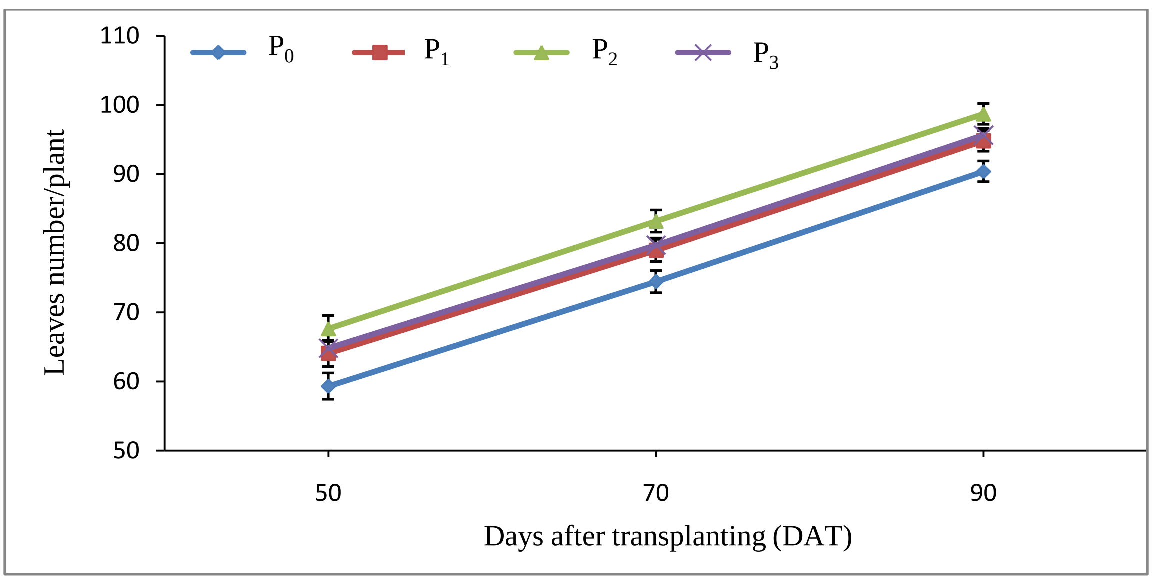


Figure 5. Effect of phosphorus on number of leaves of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.90, 1.59, 1.47 at 50, 70 and 90 DAT.

Table 3. Effect of population density and phosphorus on number of leaves of golden rod at different days after transplanting

Treatments	Number of leaves per plant		
	50 DAT	70 DAT	90 DAT
D_1P_0	49.33 h	63.53 f	79.53 f
D_1P_1	67.47 c	84.13 c	99.60 c
D_1P_2	67.53 c	83.00 c	99.20 c
D_1P_3	61.13 ef	76.77 d	92.43 d
D_2P_0	58.27 g	73.60 e	89.30 e
D_2P_1	70.20 b	84.20 c	100.2 c
D_2P_2	72.40 b	87.83 b	103.8 b
D_2P_3	59.00 fg	75.00 de	91.00 de
D_3P_0	58.07 g	73.73 e	89.40 e
D_3P_1	64.00 d	77.67 d	93.67 d
D_3P_2	77.20 a	91.87 a	107.2 a
D_3P_3	63.00 de	77.67 d	93.20 d
$LSD_{0.05}$	2.265	2.753	2.553
CV (%)	8.94	12.39	10.57

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.3 Number of side shoots per plant

Variation was found in respect of number of side shoot per plant. Significant influence was observed by different population density at different days after transplanting (DAT) (Figure 6 and Appendix V). From the experiment it was found that the maximum number of side shoot per plant (4.60, 6.71 and 11.76 at 70, 80 and 90 DAT) was recorded from D_3 (62500 plants ha^{-1}) which is statistically identical with D_2 (83333 plants ha^{-1}) at 70 and 80 DAT. Again, the minimum number of side shoots per plant of golden rod (3.27, 4.95 and 9.69) was achieved from D_1 (125000 plants ha^{-1}). This result was obtained might be due to in lower population density, plants get more space for tillering. Similar result was observed by Amira and Sewedan (2014).

Significant variation for different levels of phosphorus on number of side shoot per plant was observed at different days after transplanting (DAT) (Figure 7 and Appendix V). From the study it was found that the maximum number of side shoot per plant (4.64, 6.98 and 11.49) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) which was statistically same with P_3 (150 kg P_2O_5 ha^{-1}) at 70 DAT. Another way the minimum number of side shoot per plant (3.47, 5.40 and 10.16) was from P_0 (Control). Such result obtained from the present study might be due to optimization of nutrient application. Similar results were observed by Patel and Desai (2010) and Amin *et al*. (2012).

Highly significant variation was found by interaction effect of population density and phosphorus on number of side shoot per plant of golden rod at different days after transplanting (DAT) (Table 4 and Appendix V). From the experiment it was found that the maximum number of side shoot per plant (12.57) was found in D_3P_2 followed by D_2P_0 (11.60), D_2P_2 (11.87) and D_3P_3 (11.83). On the other hand, the minimum number of side shoot per plant (8.50) was recorded from D_1P_0 which was statistically identical with D_1P_3 (9.00) and D_3P_0 (8.57) at 90 DAT.

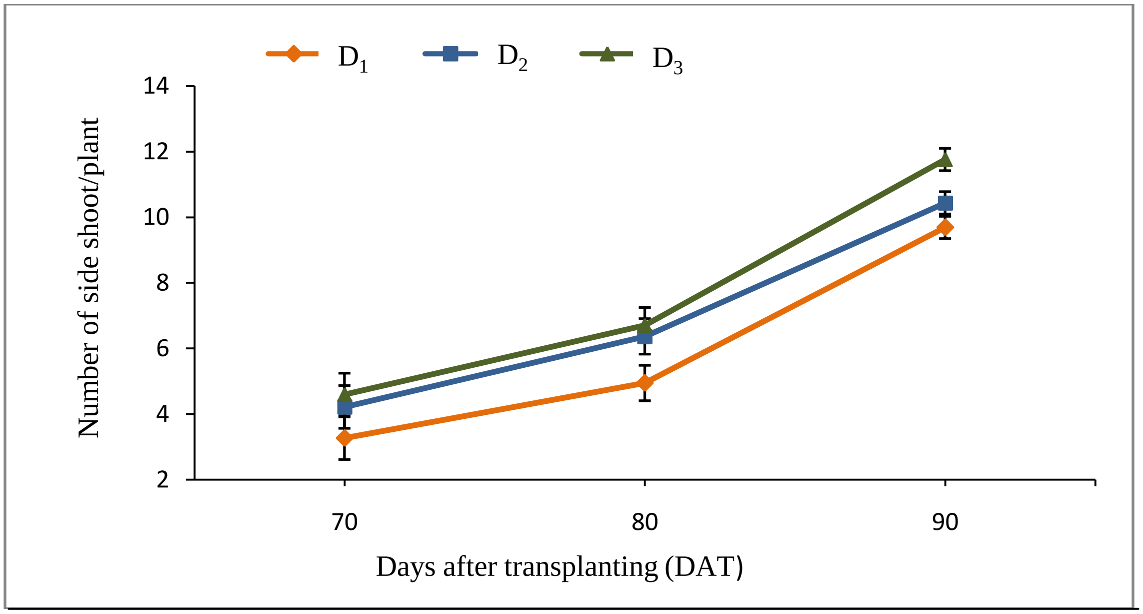


Figure 6. Effect of population density on number of side shoots per plant of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.65, 0.54, 0.34 at 70, 80 and 90DAT.

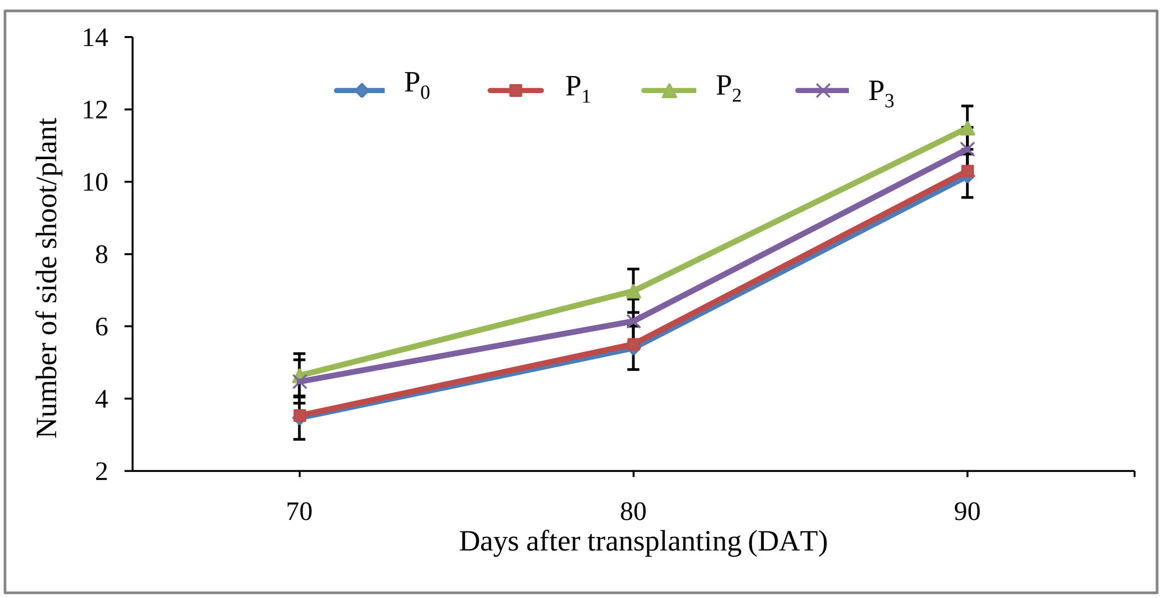


Figure 7. Effect of phosphorus on number of side shoots per plant of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.69, 0.61, 0.315 at 70, 80 and 90DAT.

Table 4. Effect of population density and phosphorus on number of side shoots per plant of golden rod at different days after transplanting

Treatments	Number of side shoots per plant		
	70 DAT	80 DAT	90 DAT
D_1P_0	2.13 f	3.73 e	8.50 f
D_1P_1	2.33 f	6.00 cd	10.80 de
D_1P_2	3.93 d	6.13 cd	10.90 de
D_1P_3	4.13 cd	4.27 e	9.00 f
D_2P_0	4.33 cd	6.80 bc	11.60 b
D_2P_1	4.27 cd	6.73 bc	11.53 bc
D_2P_2	5.13 ab	7.12 b	11.87 b
D_2P_3	4.67 bc	6.20 cd	11.00 cd
D_3P_0	3.20 e	3.80 e	8.57 f
D_3P_1	3.80 d	5.67 d	10.37 e
D_3P_2	5.33 a	8.60 a	12.57 a
D_3P_3	5.07 ab	7.07 b	11.83 b
$LSD_{0.05}$	0.5219	0.778	0.569
CV (%)	8.472	13.59	12.48

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.4 Height of side shoots

Height of side shoots showed significant due to different population density of golden rod at different days after transplanting (Figure 8 and Appendix VI). From the experiment, the maximum height of side shoots (40.81 and 46.23 cm at 70 and 90 DAT) was recorded from D_1 (125000 plants ha^{-1}) and the minimum height of side shoots (38.38 and 40.70 cm) was achieved from D_3 (62500 plants ha^{-1}).The results obtained from D_2 (83333 plants ha^{-1}) were medium. The height of side shoots length was obtained from closer spacing due to densely populated golden rod faced competition for light. So they increased vertically than the less densely populated plants. Similar result obtained by Amira and Sewedan (2014).

Height of side shoots (cm) of golden rod was significantly affected by different levels of phosphorus at different days after transplanting (DAT) (Figure 9 and Appendix VI). From the study it was found that the maximum height of side shoots (49.12 and 53.33 cm at 70 and 90 DAT) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed P_3 (150 kg P_2O_5 ha^{-1}). Again, lowest height of side shoots (35.63 and 37.91 cm) was achieved from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}). Such results were obtained due to cause of balance nutrition in the soil in respect of P_2O_5. Similar result was observed by Patel and Desai (2010).

Significant variation was found by interaction effect of population density and phosphorus on height of side shoots of golden rod at different days after transplanting (DAT) (Table 5 and Appendix VI). Results indicated that the maximum height of side shoot (57.06 cm) at 90 DAT was found in D_1P_2 followed D_2P_2 (49.81 cm) and D_3P_2 (53.13 cm). On the contrary the minimum height of side shoots (26.68 cm) was achieved from in D_3P_0 followed by D_1P_1 (37.84 cm) and D_3P_1 (38.96 cm). Similar result was found from the treatment combination of D_2P_0, D_2P_1, D_1P_0 and D_3P_3 with each other but completely separate from D_1P_2 and D_3P_0.

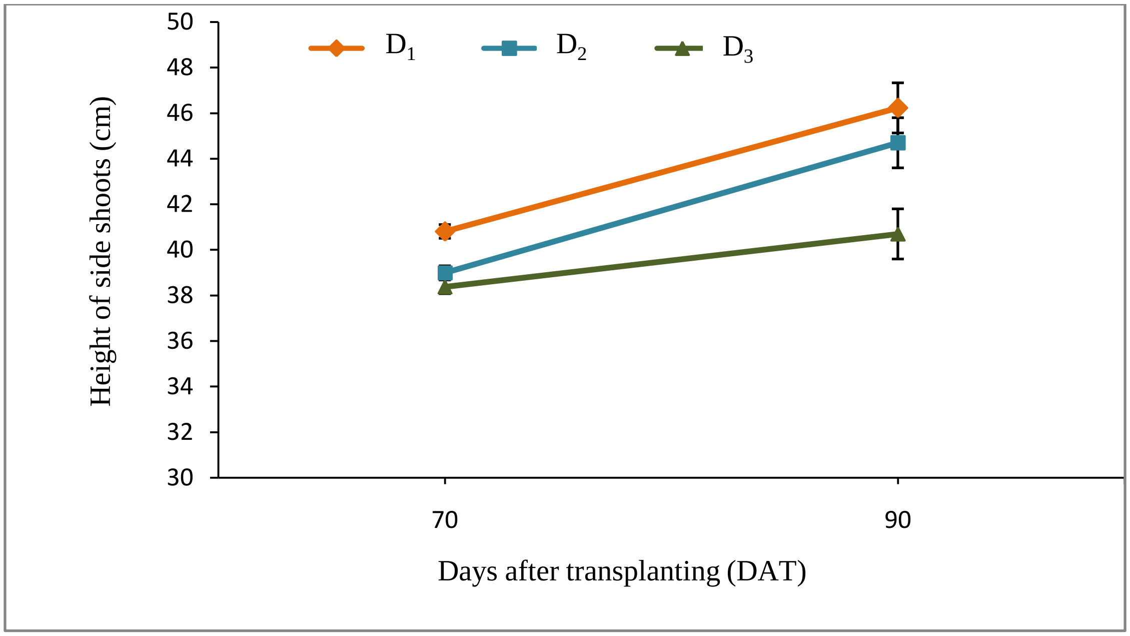


Figure 8. Effect of population density on side shoot height of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.32, 1.11 at 70 and 90DAT.

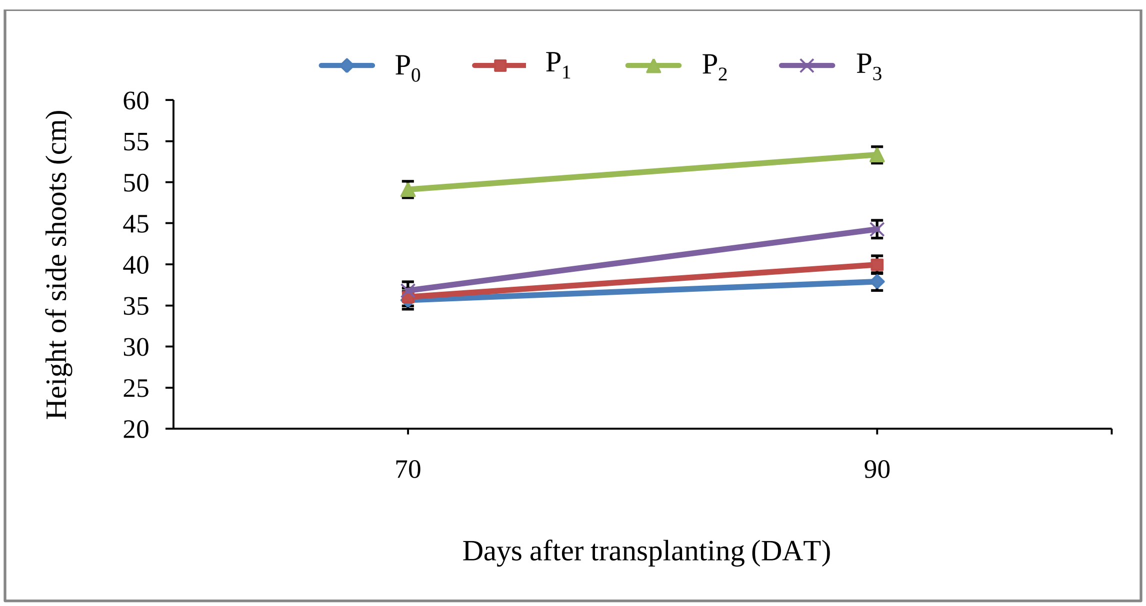


Figure 9. Effect of phosphorus on side shoot height of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.08, 1.28 at 50 and 90DAT.

Table 5. Effect of population density and phosphorus on side shoots height of golden rod at different days after transplanting

Treatments	Height of side shoots (cm)	
	70 DAT	90 DAT
D_1P_0	40.36 c	43.91 de
D_1P_1	32.36 f	37.84 f
D_1P_2	52.63 a	57.06 a
D_1P_3	35.90 e	46.10 d
D_2P_0	36.66 de	43.16 e
D_2P_1	36.37 de	43.11 e
D_2P_2	47.39 b	49.81 c
D_2P_3	37.57 de	42.74 e
D_3P_0	31.06 f	26.68 g
D_3P_1	38.15 d	38.96 f
D_3P_2	47.36 b	53.13 b
D_3P_3	36.96 de	44.02 de
$LSD_{0.05}$	1.846	2.221
CV (%)	10.81	9.47

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.5 Spike length

Different population density had significant effect on spike length (cm) of golden rod at different days after transplanting (DAT) (Figure 10 and Appendix VII). From the study it was found that the height spike length (79.92 and 92.20 cm at 70 and 90 DAT) was recorded from D_1 (125000 plants ha^{-1}) and the lowest spike length of (75.60 and 89.48 cm) was achieved from D_3 (62500 plants ha^{-1}) which was statistically identical with D_2 (83333 plants ha^{-1}) at 70 and 90 DAT. In higher population density, spike length increased most probably due to individual plants wanted to avoid the shading effect of its neighbors and enable it to acquire more of the light resources. Xiao *et al.* (2006) stated that higher population density gave higher spike length.

Significant influence was found for spike length (cm) by different levels of phosphorus at different days after transplanting (DAT) (Figure 11 and Appendix VII). From the experiment it was found that the highest spike length of golden rod (86.69 and 93.97 cm at 70 and 90 DAT) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_1 (100 kg P_2O_5 ha^{-1}) and P_3 (150 kg P_2O_5 ha^{-1}) and the lowest spike length (71.56 and 88.52 cm) was achieved from P_0 (Control). Such result obtained from the present study might be due to status of plant nutrients that applied to the soil and optimization of nutrient application. Similar results were found from the findings of Yadav (2007) and Amin *et al.* (2012).

Spike length of golden rod was significantly affected by interaction effect of population density and phosphorus at different days after transplanting (DAT) (Table 6 and Appendix VII). From the study it was found that the highest spike length (97.13 cm) at 90 DAT was found in D_1P_2 followed D_2P_2 (90.40cm) and D_3P_2 (95.60cm). Quite the reverse, the lowest spike length (81.68 cm) was recorded from D_3P_0 which was statistically identical with D_2P_3 (81.73 cm) at 90 DAT followed by D_1P_0, D_2P_0 and D_3P_3 at all growth stages.

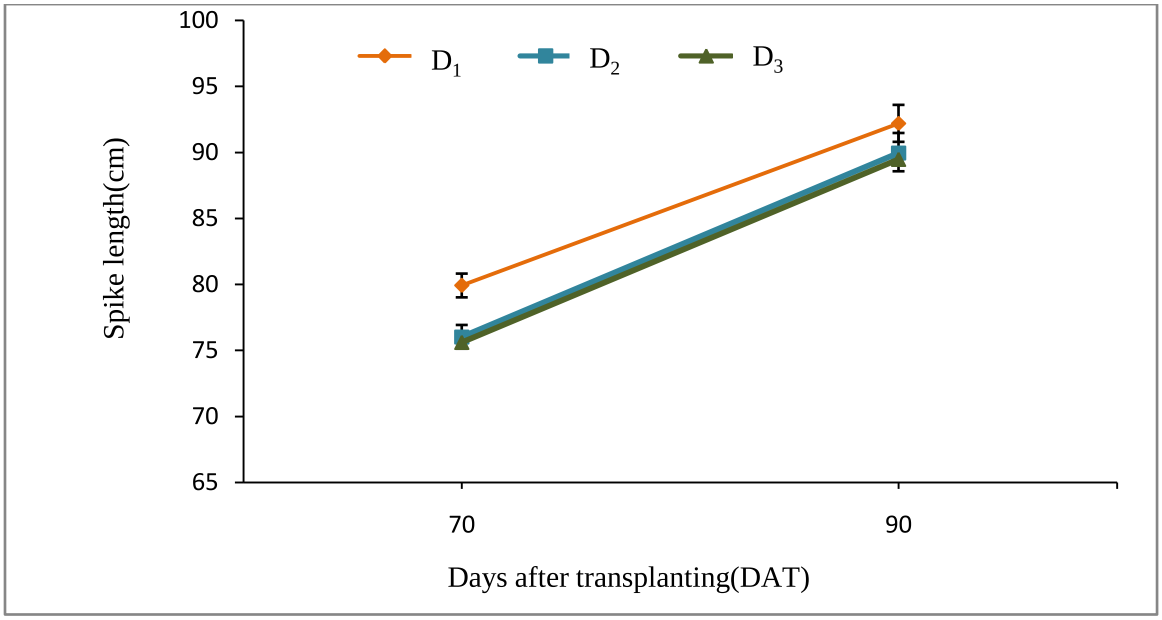


Figure 10. Effect of population density on spike length of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.91, 1.40 at 70 and 90DAT.

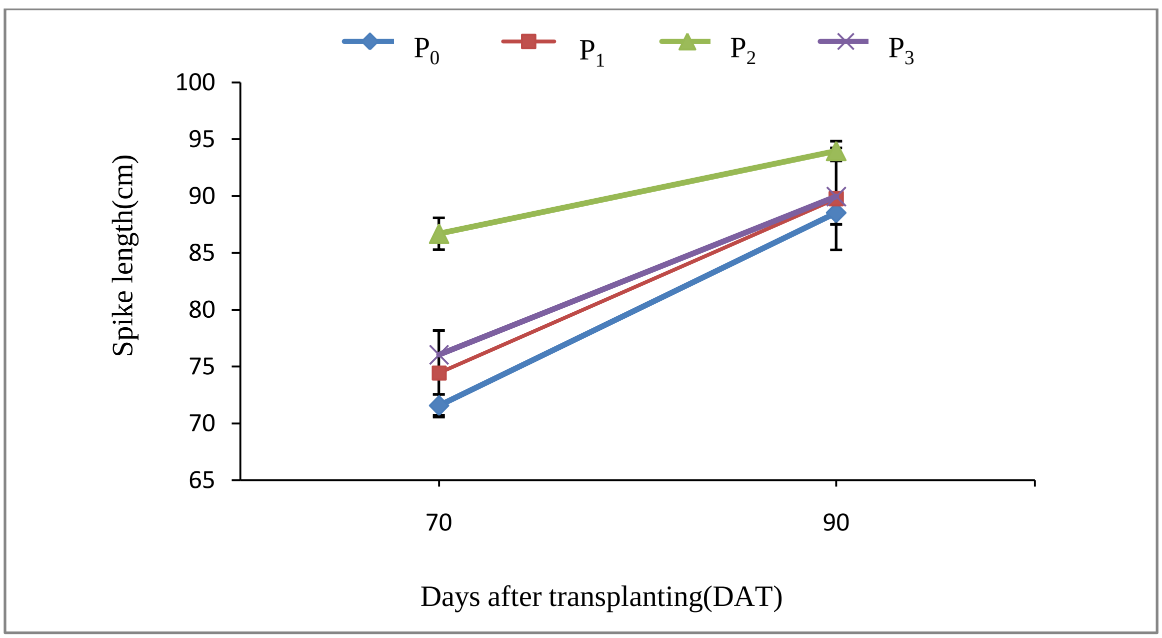


Figure 11. Effect of phosphorus on spike length of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.44, 0.86 at 70 and 90DAT.

Table 6. Effect of population density and phosphorus on spike length of golden rod at different days after transplanting

Treatments	Spike length (cm)	
	70 DAT	90 DAT
D_1P_0	85.27 b	87.13 f
D_1P_1	71.60 ef	92.07 cd
D_1P_2	89.27 a	97.13 a
D_1P_3	73.53 d	95.91 b
D_2P_0	70.33 f	90.67 e
D_2P_1	81.72 c	93.13 c
D_2P_2	84.53 b	90.40 e
D_2P_3	70.03 f	81.73 g
D_3P_0	67.53 g	81.68 g
D_3P_1	72.51 de	90.40 e
D_3P_2	86.27 b	95.60 b
D_3P_3	73.60 d	90.73 e
$LSD_{0.05}$	1.839	1.098
CV (%)	13.273	9.647

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

Plate 5. Effect of population density and phosphorus on spike length of golden rod

4.6 Rachis length

The variation in terms of rachis length among different population density of golden rod was found to be significant at different days after transplanting (DAT) (Figure 12 and Appendix VIII). From the study, the longest rachis length of golden rod (21.08 and 23.08 cm at 70 and 90 DAT) was recorded from D_1 (125000 plants ha^{-1}) followed by D_2 (83333 plants ha^{-1}) and the shortest rachis length (18.91 and 20.92 cm at 70 and 90 DAT) was achieved from D_3 (62500 plants ha^{-1}). Rachis length was higher in densely populated plants for want of light. The result obtained from the present finding was supported by Singh and Sangama (2000).

Significant variation was found for different levels of phosphorus on spike length (cm) of golden rod at different days after transplanting (DAT) (Figure 13 and Appendix VIII). From the experiment it was found that the highest spike length (21.87 and 23.88 cm at 70 and 90 DAT) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_1 (100 kg P_2O_5 ha^{-1}). Differently, the lowest spike length (17.08 and 19.09 cm) was achieved from P_0 (Control) followed by P_3 (150 kg P_2O_5 ha^{-1}. Highest spike length was obtained from P_2 due to optimum phosphorus application. Such result obtained from the present finding was supported by Yadav (2007) and Amin *et al*. (2012).

Spike length was recorded at different days after transplanting and significant variation was found by interaction effect of population density and phosphorus (Table 7 and Appendix VIII). From the study it was found that the longest spike length of golden rod (25.08 cm) at 90 DAT was found in D_1P_2 followed by D_1P_3 (24.21cm) and statistically similar with D_1P_1 (24.69 cm). On the contrary the shortest spike length of golden rod (18.32 cm) at 90 DAT was found from D_1P_0 followed by D_2P_0 (19.53 cm), D_3P_0 (19.53 cm).

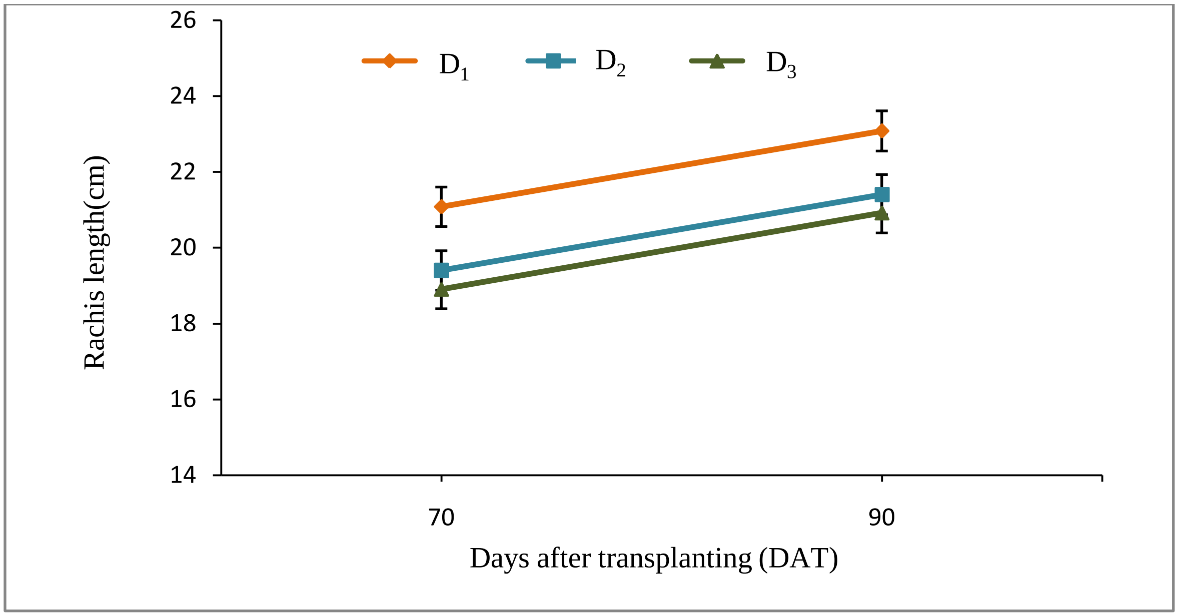


Figure 12. Effect of population density on rachis length of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing LSD $_{0.05}$ value of 0.52, 0.53 at 70 and 90 DAT.

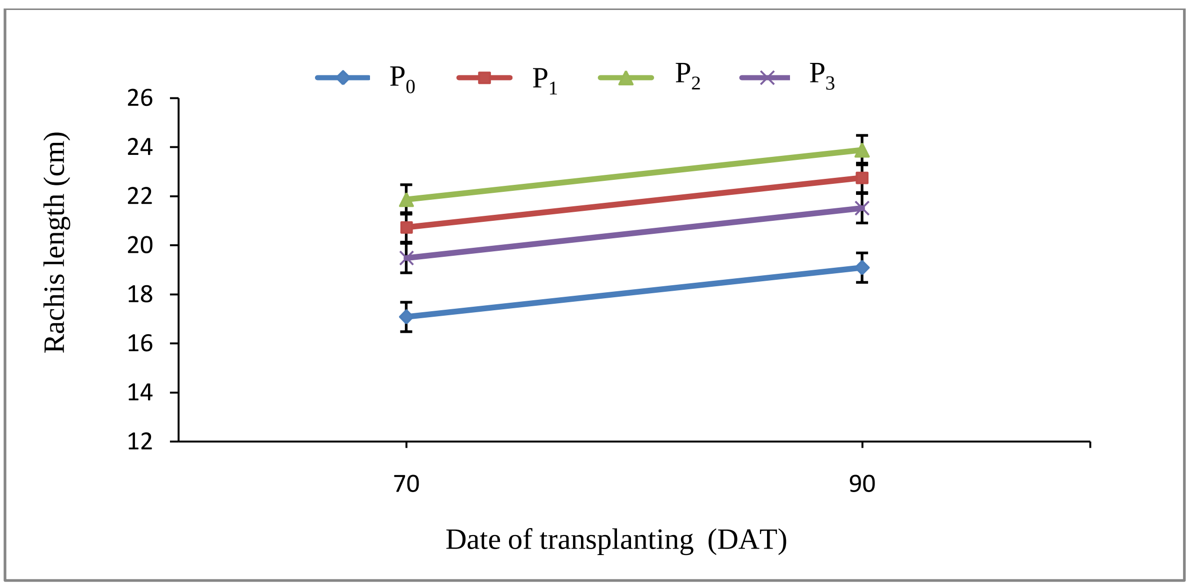


Figure 13. Effect of phosphorus on rachis length of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.59, 0.57 at 70 and 90 DAT.

Table 7. Effect of population density and phosphorus on rachis length of golden rod at different days after transplanting

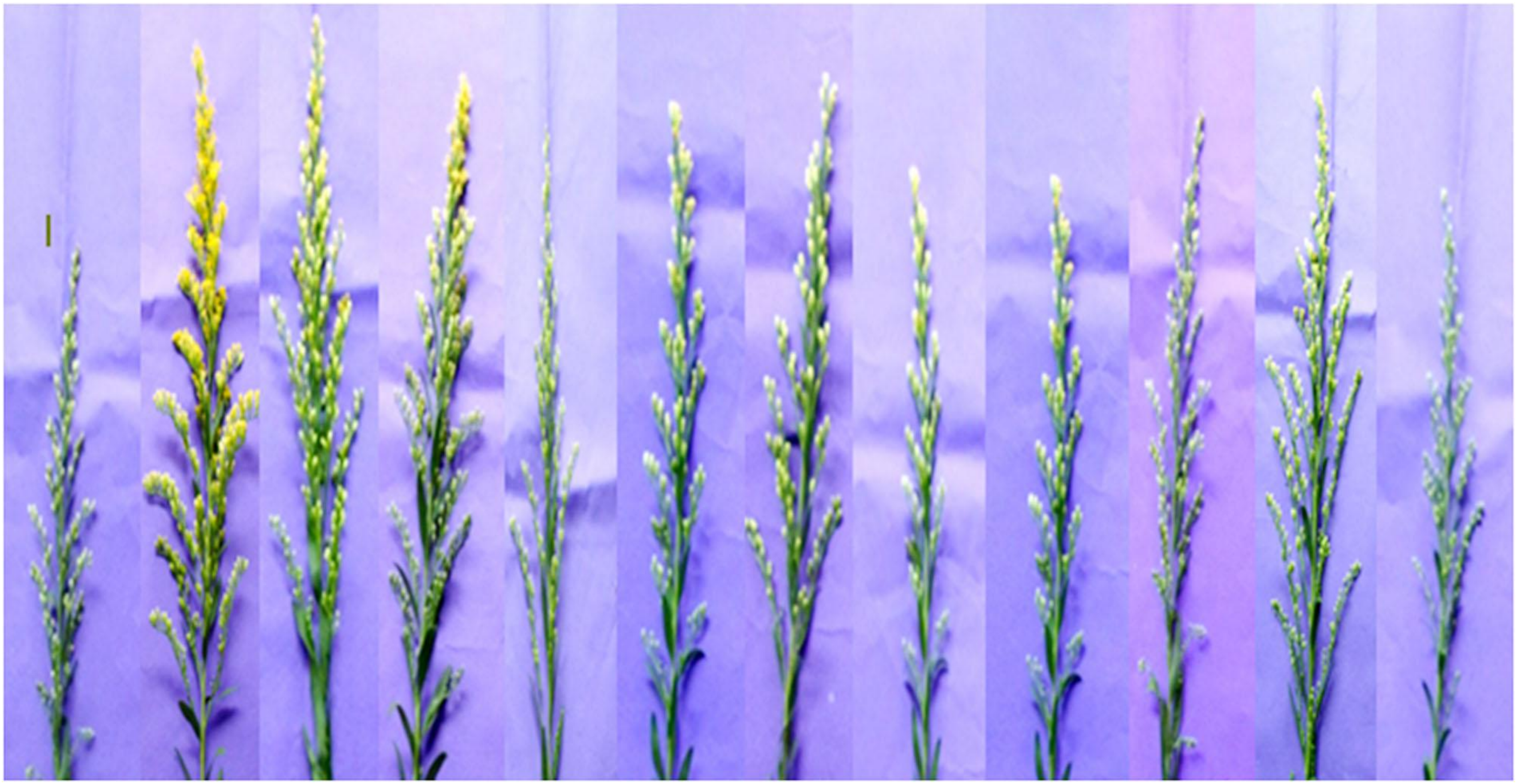
Treatments	Rachis length (cm)	
	70 DAT	90 DAT
D_1P_0	16.30 h	18.32 h
D_1P_1	22.72 ab	24.69 ab
D_1P_2	23.07 a	25.08 a
D_1P_3	22.23 b	24.21 b
D_2P_0	17.43 g	19.42 g
D_2P_1	20.33 d	22.35 d
D_2P_2	21.50 c	23.49 c
D_2P_3	18.33 f	20.32 f
D_3P_0	17.52 g	19.53 g
D_3P_1	19.14 e	21.15 e
D_3P_2	21.04 c	23.05 c
D_3P_3	17.93 fg	19.96 fg
$LSD_{0.05}$	0.5667	0.5817
CV (%)	6.874	9.367

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

18.32cm 24.69cm 25.08cm 24.21cm 19.42cm 22.35cm 23.49cm 20.32cm 19.53cm 21.15cm 23.05cm 19.96cm



D_1P_0 D_1P_1 D_1P_2 D_1P_3 D_2P_0 D_2P_1 D_2P_2 D_2P_3 D_3P_0 D_3P_1 D_3P_2 D_3P_3

Plate 6. Effects of population density and phosphorus on rachis length of golden rod

4.7 Number of spikelet per spike

Recorded data on number of spikelet per spike at different days after transplanting (DAT) was statistically significant by different population density of golden rod (Figure 14 and Appendix IX). From the study it was found that the highest number of spikelet per spike (27.09 and 31.57 at 70 and 90 DAT) was recorded from D_3 (62500 plants ha^{-1}) where the lowest number of spikelet per spike (25.39 and 29.53) was achieved from D_1 (125000 plants ha^{-1}) and result recorded from D_2 (83333 plants ha^{-1}) gave intermediate result among the treatments. This result might be due to plants obtained better micro climate for producing more spikelet number. Similar results were found by Shiraz and Maurya (2005), Sharma and Gupta (2003) and Bijimol and Singh (2001).

Significant influence was observed by different levels of phosphorus on number of spikelet per spike of golden rod at different days after transplanting (DAT) (Figure 15 and Appendix IX). From the study it was found that the highest number of spikelet per spike (27.83 and 32.38 at 70 and 90 DAT) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_3 (150 kg P_2O_5 ha^{-1}) where P_0 (100 kg P_2O_5 ha^{-1}) gave the lowest number of spikelet per spike (25.31 and 28.28) followed by P_1 (100 kg P_2O_5 ha^{-1}). The highest number of spikelet per spike was obtained from P_2 due to higher P_2O_5. The result found from the present study was in conformity with the findings of Yadav (2007) and Patel *et al*. (2006).

Interaction effect of population density and phosphorus had significant influence on number of spikelet per spike of golden rod at different days after transplanting (DAT) (Table 8 and Appendix IX). From the study it was obtained that the highest number of spikelet per spike (33.07) at 90 DAT was found in D_3P_2 which was statistically similar with D_2P_2 (32.73) at 90 DAT followed by D_1P_3 (31.47), D_2P_3 (31.60), D_3P_1 (31.67) and D_3P_3 (31.73). On the other hand, the lowest number of spikelet per spike (26.52) was from D_1P_0 followed by D_1P_1 (28.80), D_2P_0 (28.53) and D_3P_0 (29.80).

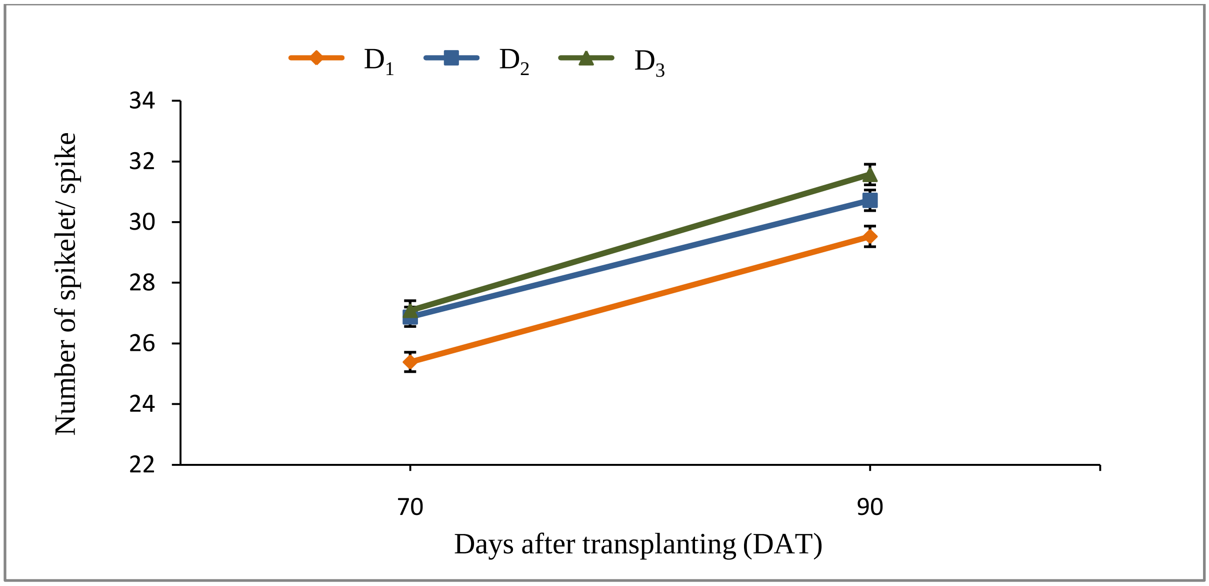


Figure 14. Effect of population density on number of spikelet per spike of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.32, 0.34 at 70 and 90 DAT.

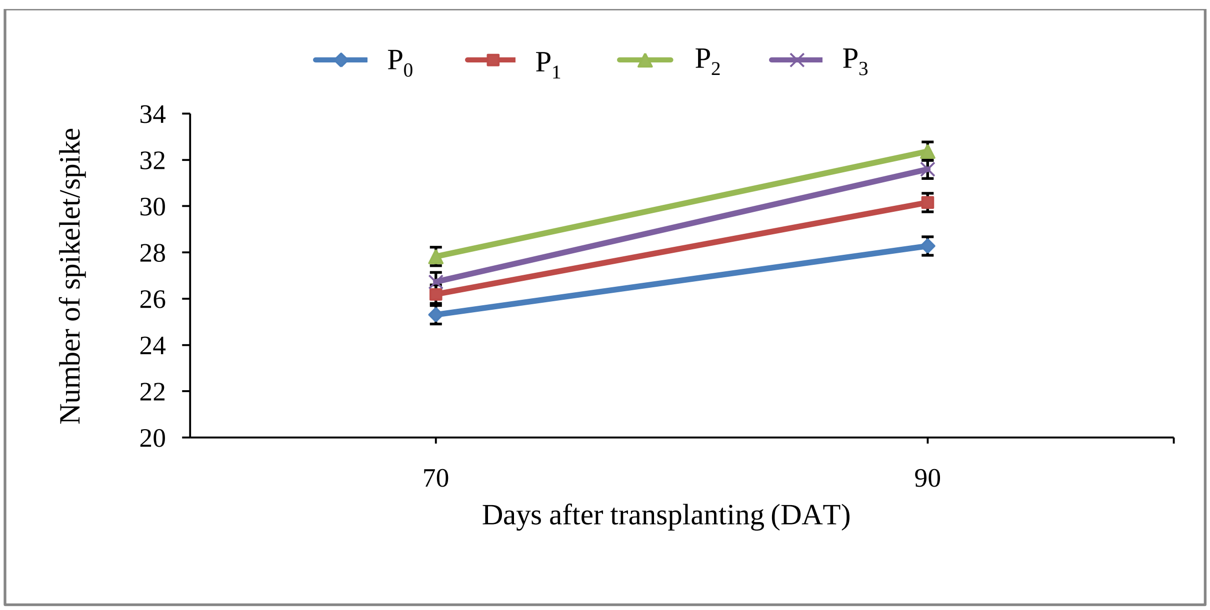


Figure 15. Effect of phosphorus on number of spikelet per spike of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.32, 0.41 at 70 and 90DAT.

Table 8. Effect of population density and phosphorus on number of spikelet per spike of golden rod at different days after transplanting

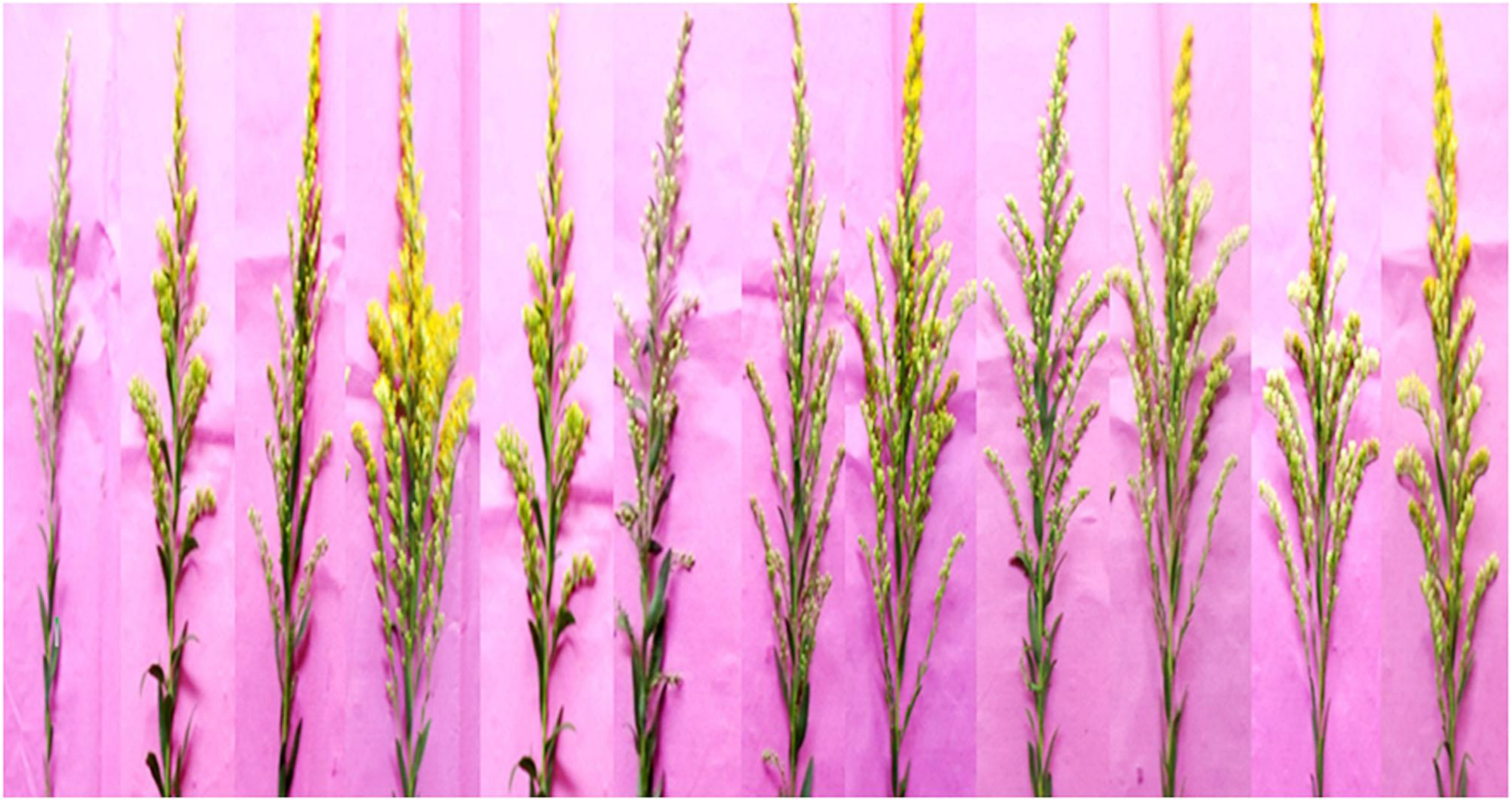
Treatments	Number of spikelet per spike	
	70 DAT	90 DAT
D_1P_0	23.95 e	26.52 f
D_1P_1	28.47 b	28.80 de
D_1P_2	24.07 e	31.33 c
D_1P_3	25.05 de	31.47 bc
D_2P_0	25.53 cd	28.53 e
D_2P_1	25.07 de	30.00 d
D_2P_2	29.33 ab	32.73 ab
D_2P_3	28.40 b	31.60 bc
D_3P_0	26.33 cd	29.80 de
D_3P_1	26.67 c	31.67 bc
D_3P_2	30.20 a	33.07 a
D_3P_3	25.15 de	31.73 bc
$LSD_{0.05}$	1.255	1.243
CV (%)	12.75	13.36

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

26.52 28.80 31.33 31.47 28.53 30.00 32.73 31.60 29.80 31.6 33.07 31.73



D_1P_0 D_1P_1 D_1P_2 D_1P_3 D_2P_0 D_2P_1 D_2P_2 D_2P_3 D_3P_0 D_3P_1 D_3P_2 D_3P_3

Plate 7. Effect of population density and phosphorus on spikelet no. per spike

4.8 Number of spike per hill

Effect of different population density on number of spike per hill was found significant at different days after transplanting (Figure 16 and Appendix X). From the study it was found that the highest number of spike per hill (5.42 and 7.25 at 70 and 90 DAT) was recorded from D_3 (62500 plants ha^{-1}) where the lowest number of spike per hill (4.79 and 6.49) was achieved from D_1 (125000 plants ha^{-1}) and D_2 (83333 plants ha^{-1}) gave intermediate results among the treatments. The highest number of spikes per hill was produced in lower population density possibly due to more side shoots proliferation in each hill. Similar results were found from findings of Shiraz and Maurya (2005), Sharma and Gupta (2003), Bijimol and Singh (2001) and Misra *et al.* (2000).

Significant variation was observed for different levels of phosphorus on number of spike per hill of golden rod at different days after transplanting (Figure 17 and Appendix X). From the study it was found that the highest number of spike per hill (5.62 and 7.44 at 70 and 90 DAT) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_3 (150 kg P_2O_5 ha^{-1}). Again, the lowest number of spike per hill (4.17 and 5.90) was achieved from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}) at all growth stages. Due to availability of P_2O_5 at optimum dose more spikes were produced in P_2 (125 kg P_2O_5 ha^{-1}). Similar result was found by Yadav (2007).

Significant variation was found by interaction effect of population density and phosphorus on number of spike per hill of golden rod at different days after transplanting (Table 9 and Appendix X). From the experiment it was found that the highest number of spike per hill (7.65) at 90 DAT was found in D_3P_2 followed by D_3P_3 (7.52) and D_3P_1 (7.44). The lowest number of spike per hill (5.44) was achieved from D_1P_0 followed by D_2P_0 (5.87), D_1P_1 (6.58) and D_3P_0 (6.40). The results obtained from the treatment combination of D_1P_2, D_2P_1, D_2P_2, D_2P_3 and D_3P_1 were close to each other but significantly different with each other.

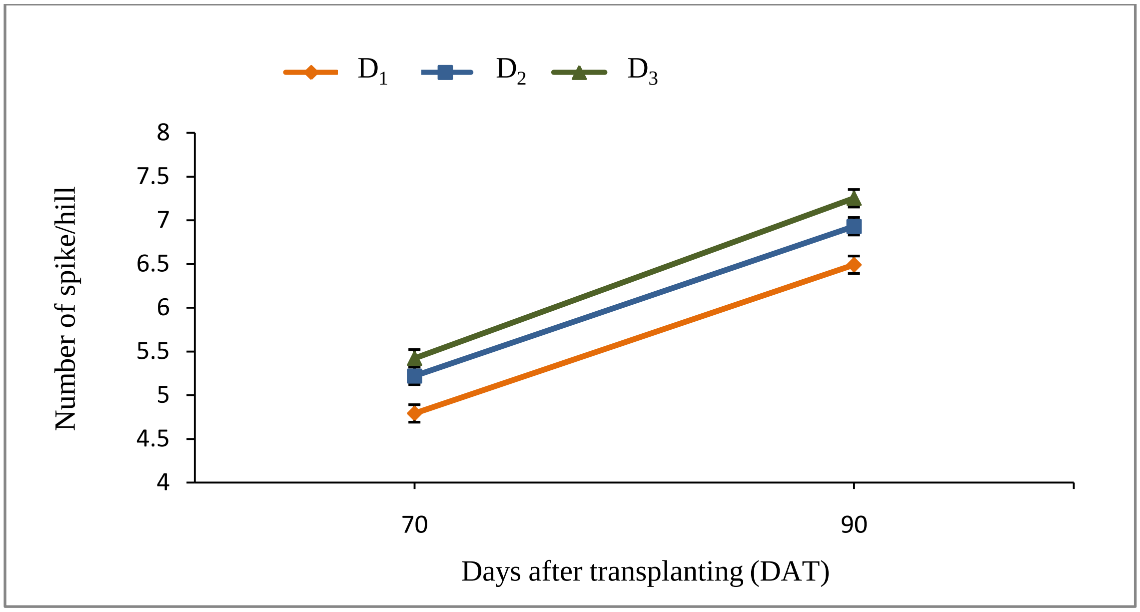


Figure 16. Effect of population density on number of spike per hill of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.10, 0.10 at 70 and 90DAT.

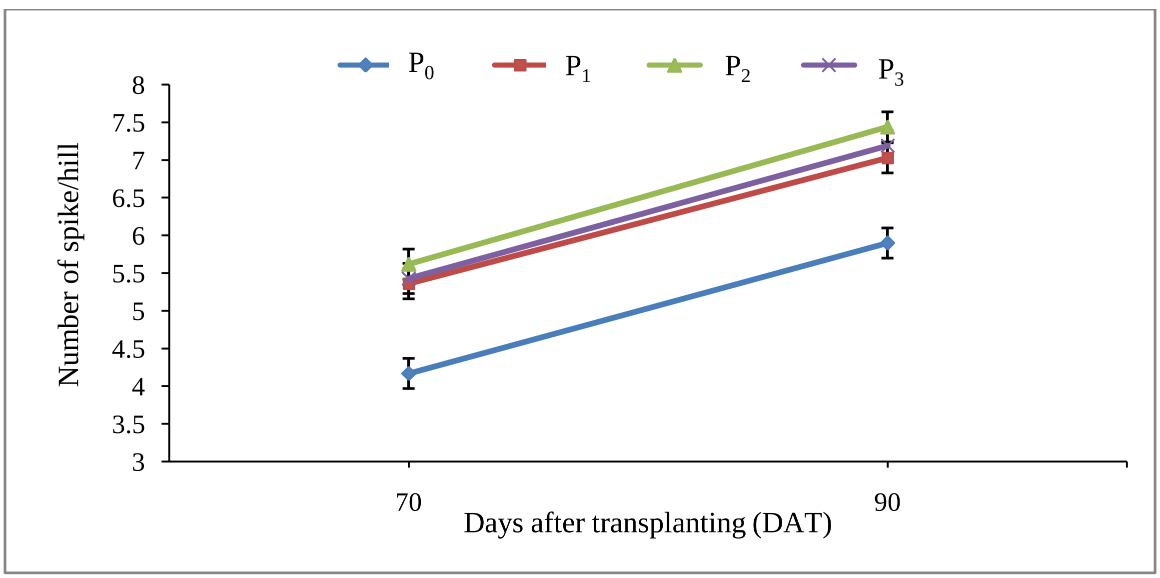


Figure 17. Effect of phosphorus on number of spike per hill of golden rod at different days after transplanting. P_0 - Control, P_1 -100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 - 50 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 0.16, 0.12 at 70 and 90DAT.

Table 9. Effect of population density and phosphorus on number of spike per hill of golden rod at different days after transplanting

Treatments	Number of spike per hill	
	70 DAT	90 DAT
D_1P_0	3.80 j	5.44 k
D_1P_1	4.90 g	6.58 h
D_1P_2	5.45 e	7.23 e
D_1P_3	5.02 f	6.70 g
D_2P_0	4.12 i	5.87 j
D_2P_1	5.52 d	7.06 f
D_2P_2	5.64 b	7.43 c
D_2P_3	5.60 c	7.34 d
D_3P_0	4.58 h	6.40 i
D_3P_1	5.65 b	7.44 c
D_3P_2	5.76 a	7.65 a
D_3P_3	5.68 b	7.52 b
$LSD_{0.05}$	0.068	0.109
CV (%)	11.78	10.68

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.9 Number of harvested spike per plot

The recorded data on number of harvested spike per plot at different days after transplanting and also for total harvested spike per plot was found significant (Figure 18 and Appendix XI). From the study it was found that the highest number of harvested spike per plot (56.65 and 70.05 at 70 and 90 DAT respectively) was recorded from D_1 (125000 plants ha^{-1}) followed by D_2 (83333 plants ha^{-1}). The highest total number of harvested spike plot (126.70) was also recorded from D_1.Though more side shoots were obtained from D_3 (62500 plants ha^{-1}) because of wider spacing between plants and they have got more spacing for tillering. But when number of spike per plot and total number of spike per plot was calculated highest result was found in D_1 because the highest number of plant (24 plants $plot^{-1}$) was accommodated in this plot. Again, the lowest number of harvested spike per plot (23.02 and 35.01) was recorded from D_3. The lowest total number of harvested spike plot (58.03) was also recorded from D_3 due to lowest number of plants per plot (12 plants $plot^{-1}$) was presented in D_3. Similar result was obtained from the findings of Singh and Sangama (2000).

Significant difference among different phosphorus levels on number of harvested spike per hill of golden rod was found at different days after transplanting (DAT) and also for total harvested spike plot (Figure 19 and Appendix X). From the experiment it was found that the highest number of harvested spike per plot (42.84 and 56.23 at 70 and 90 DAT respectively) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_3 (150 kg P_2O_5 ha^{-1}). The highest total number of harvested spike per plot (99.07) was also recorded from P_2 followed by P_3. Due to optimum dose of P_2O_5 (125 kg ha^{-1}) this type of result was found. Again, the lowest number of harvested spike per plot (32.50 and 38.93 at 70 and 90 DAT respectively) was achieved from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}).

The lowest total number of harvested spike plot (71.43) was also recorded from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}). In case of control and lower dose of

P_2O_5 plant could not get proper nutrition. Similar result was found by Yadav (2007).

Significant variation was found by interaction effect of population density and phosphorus on number of harvested spike per plot of golden rod at different days after transplanting (DAT) and also for total harvested spike per plot (Table 10 and Appendix XI). From the experiment it was observed that the highest number of harvested spike per plot (64.32 and 80.20 at 70 and 90 DAT respectively) was found in D_1P_2 followed by D_1P_3 and D_1P_1. The highest total number of harvested spike per plot (144.52) was also recorded from D_1P_2 followed by D_1P_3 and D_1P_1. On the other hand, the lowest number of harvested spike per plot (20.50 and 27.30) was achieved from D_3P_0 followed by D_2P_0, D_3P_1, D_3P_2 and D_3P_3. The lowest total number of harvested spike per plot (47.80) was also recorded from, D_3P_0 followed by D_2P_0, D_3P_1, D_3P_2 and D_3P_3. The results obtained from the treatment combination of D_2P_1, D_2P_2 and D_2P_3 gave medium result compared to highest and lowest number of harvested spike per plot at different DAT and also for total harvested spike per plot.

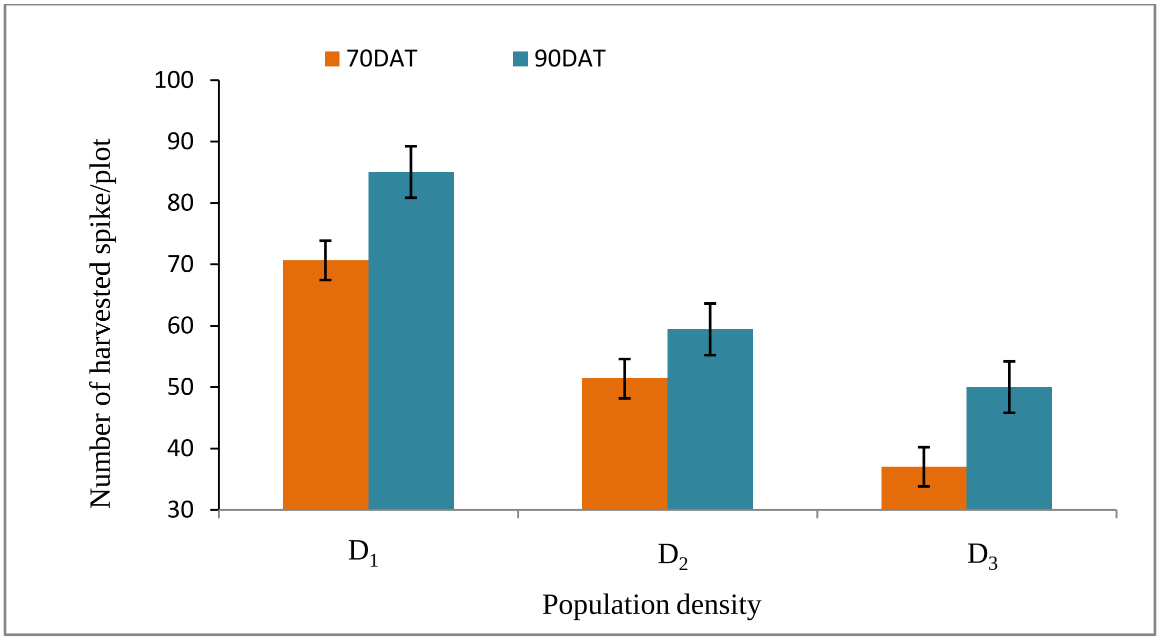


Figure 18. Effect of population density on spike per plot of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-}1, vertical error bar showing $LSD_{0.05}$ value of 3.20, 4.17 at 70 and 90DAT.

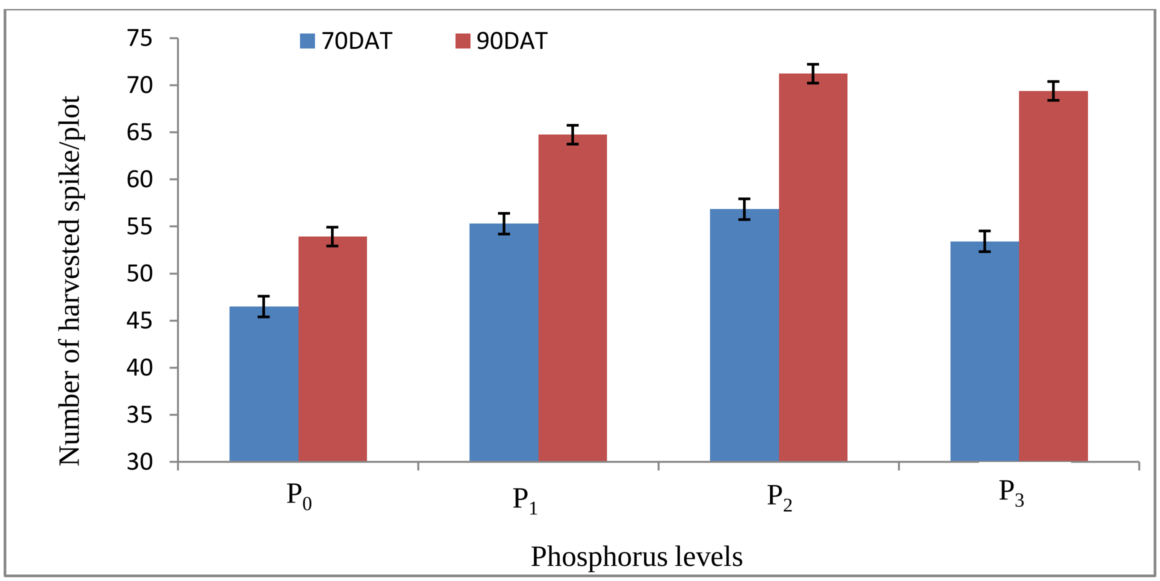


Figure 19. Effect of phosphorus on spike per plot of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}, vertical error bar showing $LSD_{0.05}$ value of 1.12, 1.02 at 70 and 90DAT.

Table 10. Effect of population density and phosphorus on spike per plot of golden rod at different days after transplanting

Treatments	Number of harvested spike per plot			Number of spike per ha
	70 DAT	90 DAT	Total	
D_1P_0	46.40 d	55.16 d	101.56 d	528958 d
D_1P_1	61.22 b	67.70 c	128.92 c	671458 c
D_1P_2	64.32 a	80.20a	144.52 a	752708 a
D_1P_3	54.66 c	77.14 b	131.80 b	686458 b
D_2P_0	30.60 h	34.32 i	64.92 g	338125 h
D_2P_1	38.36 g	45.60 f	83.96 f	437292 g
D_2P_2	41.45 e	48.43 e	89.88 e	468125 e
D_2P_3	39.12 f	49.32 e	88.44 e	460625 f
D_3P_0	20.50 k	27.30 j	47.80 j	248958 *l*
D_3P_1	24.33 i	35.95 h	60.28 i	313958 k
D_3P_2	22.75 j	40.05 g	62.80 h	327083 i
D_3P_3	24.50 i	36.74 h	61.24 h	318958 j
$LSD_{0.05}$	0.4007	0.3710	1.2841	22.389
CV (%)	7.489	10.954	9.379	16.581

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.10 Number of spike per ha

The results obtained from golden rod in terms of yield per ha (number of spike per ha) was significantly affected by different plant population density (Figure 20 and Appendix XI). Results signified that the highest number of spike per ha (659896) was recorded from D_1 (125000 plants ha^{-1}) followed by D_2 (83333 plants ha^{-1}). Again, the lowest number of spike per ha (302240) was recorded from D_3 (62500 plants ha^{-1}). The highest number of spike was obtained in highest population density, contrary the lowest number of spike was from lowest population density. Similar result was obtained from the findings of Singh and Sangama (2000).

Significant influence was found by different phosphorus levels on number of spike per ha of golden rod (Figure 21 and Appendix XI). Results specified that the highest number of spike per ha (515972) was recorded from P_2 (125 kg P_2O_5 ha^{-1}) followed by P_3 (150 kg P_2O_5 ha^{-1}). Again, the lowest number of spike per ha (372014) was observed from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}). That means plants achieved optimum P_2O_5 dose to enhance more spike. Similar result was found by Yadav (2007).

Significant variation was found by interaction effect of population density and phosphorus on number of spike per ha of golden rod at different days after transplanting (DAT) (Table 9 and Appendix XI). Results exposed that the highest number of spike per ha (752708) was found in D_1P_2 followed by D_1P_3 and D_1P_1. On the other hand, the lowest number of spike per ha (248958) was achieved from D_3P_0 followed by D_2P_0, D_3P_1, D_3P_2 and D_3P_3. The results obtained from the treatment combination of D_2P_1, D_2P_2 and D_2P_3 gave medium result compared to highest and lowest number of spike per ha.

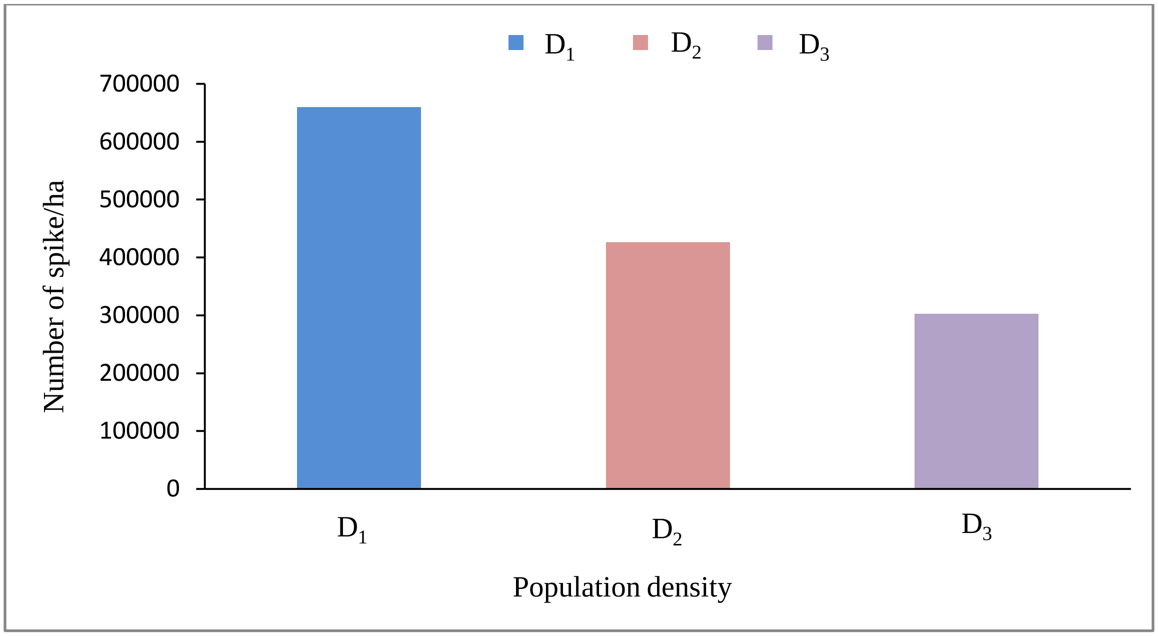


Figure 20. Effect of population density on spike per ha of golden rod at different days after transplanting. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1}, D_3 - 62500 plants ha^{-1}.

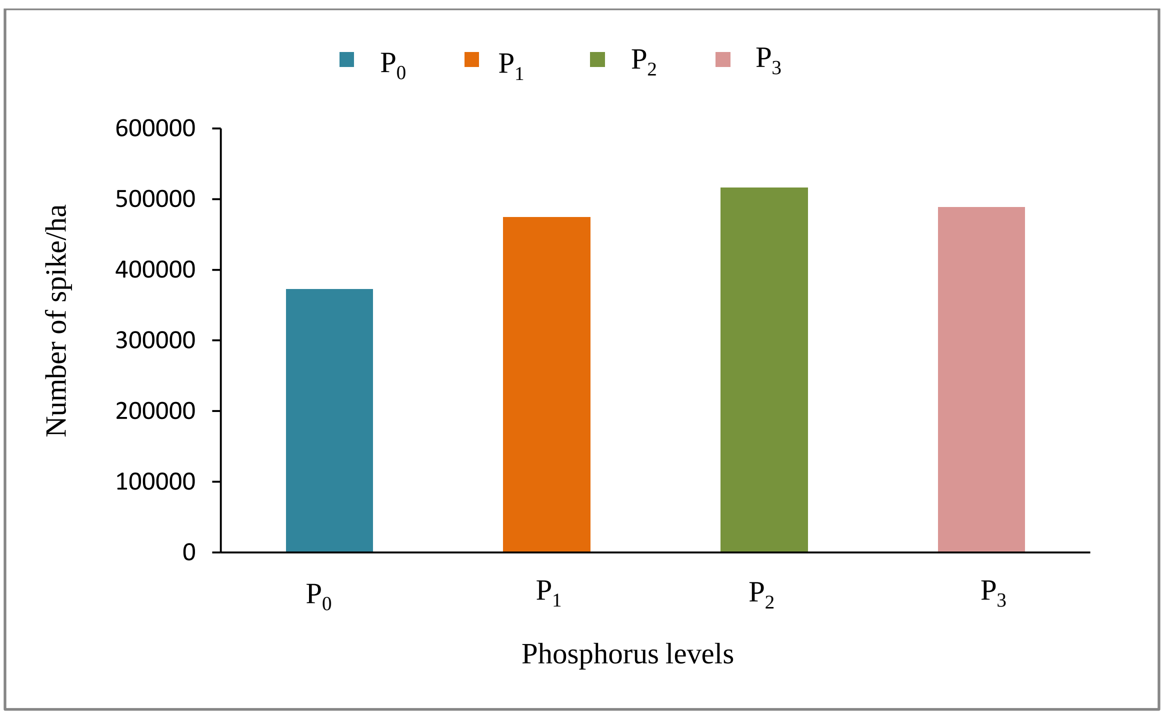


Figure 21. Effect of phosphorus on spike per ha of golden rod at different days after transplanting. P_0 - Control, P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1}, P_3 -150 kg P_2O_5 ha^{-1}.

4.11 Shelf life (days)

Significant variation was found by different population density of golden rod on shelf life (days) (Table 11 and Appendix XII). From the study it was found that the highest shelf life of golden rod (5.75 days) was recorded from D_2 (483333 plants ha^{-1}) and D_3 (62500 plants ha^{-1}) where the lowest shelf life of golden rod (5.42 days) was recorded from D_1 (125000 plants ha^{-1}). Amira and Sewedan (2014) observed that vase life is increased by reducing planting density.

Significant difference was observed by different levels of phosphorus on shelf life (days) of golden rod (Table 11 and Appendix XII). From the experiment it was found that the highest shelf life of golden rod (6.67 days) was recorded from P_3 (150 kg P_2O_5 ha^{-1}) followed by P_2 (125 kg P_2O_5 ha^{-1}) where the lowest shelf life of golden rod (4.22 days) was achieved from P_0 (Control) followed by P_1 (100 kg P_2O_5 ha^{-1}). This result was recorded possibly due to higher doses of P_2O_5 may enhance shelf life of golden rod. Similar result was found by Yadav (2007).

Significant variation was found by interaction effect of population density and phosphorus on shelf life of golden rod (Table 11 and Appendix XII). Results indicated that the highest shelf life of golden rod (6.67 days) was found in D_1P_3 (6.67 days), D_2P_3 (6.67 days) and D_3P_3 (6.67 days) which was statistically identical with D_1P_2 (6.33 days), D_2P_2 (6.33 days) and D_3P_2 (6.33 days). On the contrary, the lowest shelf life of golden rod (3.67 days) was achieved from D_1P_0 days followed by D_2P_0 (4.33 days) and D_3P_0 (4.67 days).

Table 11. Effect of population density and phosphorus on shelf life of golden rod at different days after transplanting

Treatments	Shelf life (days)
Effect of population density	
D_1	5.42 b
D_2	5.75 a
D_3	5.75 a
$LSD_{0.05}$	0.046
Effect of phosphorus	
P_0	4.22 d
P_1	5.33 c
P_2	6.33 b
P_3	6.67 a
$LSD_{0.05}$	0.044
Interaction effect of population density and phosphorus	
D_1P_0	3.67 f
D_1P_1	5.00 cd
D_1P_2	6.33 a
D_1P_3	6.67 a
D_2P_0	4.33 e
D_2P_1	5.67 b
D_2P_2	6.33 a
D_2P_3	6.67 a
D_3P_0	4.67 de
D_3P_1	5.33 bc
D_3P_2	6.33 a
D_3P_3	6.67 a
$LSD_{0.05}$	0.572
CV (%)	5.234

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.

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

4.12 Economic performances

The cost and return analysis were done and presented in Table 12. Material (A), non-material (B) and overhead costs were recorded for all the treatments of unit plot and calculated on per hectare basis (yield ha^{-1}), the price of golden rod per spike at the local market rates was considered. The total cost of production ranges between Tk. 138118 ha^{-1} and Tk. 181789 ha^{-1} among the different treatment combinations. The variation was due to different cost of number of seedlings per plot and different doses of phosphorus.

The highest cost of production Tk. 181789 ha^{-1} was involved in the treatment combination of D_1P_3 followed by D_1P_2 and D_1P_1 while the lowest cost of production Tk. 138118 ha^{-1} was involved in the combination of D_3P_0 followed by D_3P_1 and D_3P_2 (Appendix VII).

Gross return from the different treatment combinations range between Tk 149375 ha^{-1} and Tk. 402875 ha^{-1}. The highest gross return Tk 451625 ha^{-1} was obtained from the treatment combination of D_1P_2 followed by D_1P_3 and D_1P_1 where the lowest gross return Tk. 149375 ha^{-1} was found from the treatment combination of D_3P_0 followed by D_3P_1 and D_3P_3. Among the different treatment combinations D_1P_1 gave the highest net return Tk 270527 ha^{-1} while the lowest net return Tk. 11257 ha^{-1} was obtained from the treatment combination of D_3P_0.

The benefit cost ratio (BCR) was found to be the highest (2.49) in the treatment combination of D_1P_2. The lowest BCR (1.08) was recorded from the treatment combination of D_3P_0. Thus it was apparent that the population of 125000 plants ha^{-1} with phosphorus level of 125 kg P_2O_5 ha^{-1} (D_1P_2) gave the highest spike yield (752708 plants ha^{-1}) and the highest gross return (Tk. 451625 ha^{-1}). Therefore, it may be suggested that D_1P_2 gave the highest spike yield $ha^{-1.}$ Further studies in this relation should be conducted in other regions of the country before final recommendation.

Table 12. Economic performances golden rod flower production income return showing benefit cost ratio (BCR)

Treatment	Cost of production ha^{-1}	Yield ha^{-1} (Number of spike)	Gross return (Tk. ha^{-1})*	Net return (Tk. ha^{-1})	BCR
D_1P_0	177,598	528958	317375	139,777	1.79
D_1P_1	180,398	671458	402875	222,477	2.23
D_1P_2	181,098	752708	451625	270,527	2.49
D_1P_3	181,798	686458	411875	230,077	2.27
D_2P_0	152,025	338125	202875	50,850	1.33
D_2P_1	154,825	437292	262375	107,550	1.69
D_2P_2	155,525	468125	280875	125,350	1.81
D_2P_3	156,225	460625	276375	120,150	1.77
D_3P_0	138,118	248958	149375	11,257	1.08
D_3P_1	140,918	313958	188375	47,457	1.34
D_3P_2	141,618	327083	196250	54,632	1.39
D_3P_3	142,318	318958	191375	49,057	1.34

* Selling cost = Tk. 0.60 $spike^{-1}$

D_1: 125000 plants ha^{-1}
D_2: 83333 plants ha^{-1}
D_3: 62500 plants ha^{-1}

P_0: Control
P_1: 100 kg P_2O_5 ha^{-1}
P_2: 125 kg P_2O_5 ha^{-1}
P_3: 150 kg P_2O_5 ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from May 2014 to October 2014. The experiment consisted of two factors: Factor A: three levels of population density *viz*. D_1 - 125000 plants ha^{-1}, D_2 - 83333 plants ha^{-1} and D_3 - 62500 plants ha^{-1}. Factor B: four levels of phosphorus *viz*. P_0 - Control (0 kg P_2O_5), P_1 - 100 kg P_2O_5 ha^{-1}, P_2 - 125 kg P_2O_5 ha^{-1} and P_3 - 150 kg P_2O_5 ha^{-1}.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Golden rod plants were used for the study and collected from Godkhali, Jessore. Data were collected on different parameters like plant height, number of leaves per plant, number of side shoot per plant, height of side shoot per plant, length of spike, number of spike per hill, length of rachis, number of spikelet per spike, number of spike per plot, spike yield per ha by number and shelf-life of spike.

The obtained results indicated that all the studied treatments were not promising in terms of different parameters and above all spike yield of golden rod. Results revealed that different parameters were significantly influence by different levels of plant population density. It was found that the highest plant height (69.37, 86.48 and 102.50 cm at 50, 70 and 90 DAT respectively), the highest spike length (79.92 and 92.20 cm at 70 and 90 DAT respectively), highest rachis length (21.08 and 23.08 cm at 70 and 90 DAT respectively), highest height of side shoot (40.81 and 46.23 cm at 70 and 90 DAT respectively), highest number of harvested spike per plot (56.65 and 70.05 at 70 and 90 DAT respectively), highest total number of harvested spike per plot (126.70) and the highest number of spike per ha (659896) were recorded from D_1 (125000 plants ha^{-1}) but the highest shelf life of golden rod (5.75 days) was recorded from D_2 (83333 plants ha^{-1}). Again, the highest number of leaves of golden rod (66.65, 81.64 and 97.31 at 50, 70 and 90 DAT respectively), highest number of side shoot per plant (4.60, 6.71 and 11.76 at 70, 80 and 90 DAT respectively), highest number of spikelet per spike (27.09 and 31.57 at 70 and 90 DAT respectively) and highest number of spike per hill (5.42 and 7.25 at 70 and 90 DAT respectively) were recorded from D_3 (62500 plants ha^{-1}). Results also indicated that the lowest plant height (65.53, 82.48 and 99.67 cm at 50, 70 and 90 DAT respectively), lowest spike length (75.60 and 89.48 cm at 70 and 90 DAT respectively), lowest rachis length (18.91 and 20.92 cm at 70 and 90 DAT respectively), lowest number of harvested spike per plot (23.02 and 35.01 at 70 and 90 DAT respectively), lowest total number of harvested spike per plot (58.03) and lowest number of spike per ha (302240) were recorded from D_3 (62500 plants ha^{-1}). Again, the lowest number of leaves per plant (60.95, 75.75 and 91.50 at 50 and 70 DAT respectively), lowest number of side shoots per plant of golden rod (3.27, 4.95 and 9.69 at 70, 80 and 90 DAT respectively) and lowest number of spikelet $spike^{-1}$ (25.39 and 29.53 at 70 and 90 DAT respectively), lowest number of spike per hill (4.79 and 6.49 at 70 and 90 DAT respectively) and lowest shelf life of golden rod (5.42 days) were achieved from D_1 (125000 plants ha^{-1}) but the lowest height of side shoot (38.38 and 40.70 cm at 70 and 90 DAT respectively) was achieved from D_3 (62500 plant ha^{-1}).

Different levels of phosphorus applied in the golden rod field had significant effect on different parameters. Results exposed that the highest plant height (69.51, 89.40 and 107.10 cm at 50, 70 and 90 DAT respectively) was recorded from P_1 (100 kg P_2O_5 ha^{-1}) and the highest shelf life of golden rod (6.67 days) was recorded from P_3 (150 kg P_2O_5 ha^{-1}). But the highest number of leaves per plant (67.64, 83.20 and 98.70 at 50, 70 and 90 DAT respectively), the highest number of side shoot per plant (4.64, 6.98 and 11.49 at 70, 80 and 90 DAT respectively), highest spike length of golden rod (86.69 and 93.97 cm at 70 and 90 DAT respectively), highest rachis length (21.87 and 23.88 cm at 70 and 90 DAT respectively), highest number of spikelet per spike (27.83 and 32.38 at 70 and 90

DAT respectively), highest height of side shoot (49.12 and 53.33 cm at 70 and 90 DAT respectively), highest number of spike per hill (5.62 and 7.44 at 70 and 90 DAT respectively), highest number of harvested spike per plot (42.84 and 56.23 at 70 and 90 DAT respectively), highest total number of harvested spike per plot (99.07) and highest number of spike per ha (515972) were recorded from P_2 (125 kg P_2O_5 ha^{-1}). On the other hand, the lowest plant height (65.22, 81.18 and 97.00 cm at 50, 70 and 90 DAT respectively), lowest number of leaves per plant (59.33, 74.43 and 90.39 at 50, 70 and 90 DAT respectively), lowest number of side shoot per plant (3.47, 5.40 and 10.16 at 70, 80 and 90 DAT respectively), lowest spike length (71.56 and 88.52 cm at 70 and 90 DAT respectively), lowest rachis length (17.08 and 19.09 cm at 70 and 90 DAT respectively), lowest number of spikelet per spike (25.31 and 28.28 at 70 and 90 DAT respectively), lowest height of side shoot (35.63 and 37.91 cm at 70 and 90 DAT respectively), lowest number of spike per hill (4.17 and 5.90 at 70 and 90 DAT respectively), lowest number of harvested spike per plot (32.50 and 38.93 at 70 and 90 DAT respectively), lowest total number of harvested spike per plot (71.43), lowest number of spike per ha (372014) and lowest shelf life of golden rod (4.22 days) was achieved from P_0 (Control).

In terms of combined effect of population density and phosphorus levels the studied parameters were significantly influenced. Results demonstrated that the highest plant height (76.47, 95.53 and 107.90 at 50, 70 and 90 DAT respectively) and highest shelf life of golden rod (6.67 days) were found from D_1P_1 and D_1P_3 respectively. But the highest spike length (89.27 and 97.13 cm at 70 and 90 DAT respectively), highest height of side shoot (52.63 and 57.06 cm at 70 and 90 DAT respectively), highest number of harvested spike per plot (78.32 and 95.20 at 70 and 90 DAT respectively), highest total number of harvested spike per plot (173.52) and highest number of spike per ha (752708) were recorded from D_1P_2. Again, highest numbers of leaves per plant (77.20, 91.87 and 107.2 at 50, 70 and 90 DAT respectively), highest number of side shoot per plant (5.33, 8.60 and

12.57 at 70, 80 and 90 DAT respectively), highest number of spikelet per spike (30.20 and 33.07 at 70 and 90 DAT respectively) and highest number of spike per hill (5.76 and 7.65 at 70 and 90 DAT respectively) were found from D_3P_2. Similarly, the lowest number of leaves per plant (49.33, 63.53 and 79.53 at 50, 70 and 90 DAT respectively), the lowest number of side shoot per plant (2.13, 3.73 and 8.50 at 70, 80 and 90 DAT respectively), the lowest spike length of golden rod (16.30 and 18.32 cm at 70 and 90 DAT respectively), the lowest number of spikelet per spike (23.95 and 26.52 at 70 and 90 DAT respectively), the lowest number of spike per hill (3.80 and 5.44 at 70 and 90 DAT respectively) and the lowest shelf life of golden rod (3.67 days) were achieved from D_1P_0. Again, the lowest spike length (67.53 and 81.68 cm at 70 and 90 DAT respectively), lowest plant height (58.00, 74.87 and 89.20 cm at 50, 70 and 90 DAT respectively), the lowest height of side shoot (31.06 and 26.68 cm at 70 and 90 DAT respectively), the lowest number of harvested spike per plot (34.50 and 42.30 at 70 and 90 DAT respectively), lowest total number of harvested spike per plot (76.80) and lowest number of spike per ha (248958) was achieved from D_3P_0.

Among the different treatment combinations D_1P_2 gave the highest net return Tk 270527 ha^{-1} and highest gross return Tk451625ha^{-1} while the lowest net return Tk 11257 ha^{-1} and lowest gross return Tk149375 ha^{-1} were obtained from the treatment combination of D_3P_0. The benefit cost ratio (BCR) was found to be the highest (2.49) in the treatment combination of D_1P_2. Where the lowest BCR (1.08) was recorded from the treatment combination D_3P_0.

Conclusion and suggestion

From the above discussion, it may be concluded that

- In the experiment, higher population density (D_1 - 125000 plants ha^{-1}) was more effective than lower population density (D_3 - 62500 plants ha^{-1}).
- Phosphorus dose at medium level (P_2 - 125 kg P_2O_5 ha^{-1}) gave better performance for growth and flowering.
- During the investigation, the treatment combination of D_1P_2 (125000 plants ha^{-1} with 125 kg P_2O_5 ha^{-1}) was the best due to highest spike yield, net return and BCR.
- Considering the situation of the present experiment, further studies might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

REFERENCES

Alam, M.S., Iqbal, M.T., Amin, M.S. and Gaffer, M.A. 1989. Krishitattik Foshaler Utpadan O Unnayan. (In Bangali). T.M. Jubair Bin Iqbal, Manik Potal. Meghani, Sirajgong. pp. 231-239.

Amin, R.M., Jaman, F. and Uddin, A.F.M.J. 2012. Phosphorus levels on growth and flowering of *Polianthes tuberose* L. *Bangladesh Res .Pub. J.* **7**(4): 324-330.

Amira, R.O. and Sewedan, E. 2014. Effect of Planting Density and Gibberellic Acid on Quantitative and Qualitative Characteristics of *Solidago canadensis* "Tara" in Egypt. *Asian J. Crop Sci.* **6**: 89-100.

Apati, P., Kristo, T.S., Szoke, E., Kery, A., Szentmihályi, K. and Vinkler, P. 2003. Comprehensive evaluation of different Solidaginis herba extracts. Proceedings of the international conference on medicinal and aromatic plants, Budapest, Hungary, 8-11 July, 2001. Part II. *Acta Horticulturae*, **597**:69-73.

Bansal, G.L., Rana, M.C. and Upadhyay, R.G. 1995. Response of grain amaranth (*Amaranthus hypochondriacus*) to plant density. *Indian J. Agril. Sci.* **65**(11): 818-820.

Bijimol, G. and Singh, A.K. 2001. Effect of spacing and nitrogen on flowering, flower quality and post harvest life of gladiolus. *J.* Appl. Hon. Lucknow. **3**(1): 48-50.

Bose, T.K. and Som, M.G. 1986. Vegetable Crops in India. *Naya Prokash*, Calcutta Six, India. p.102.

Chapuis-Lardy, L., Vanderhoeven, S., Dassonville, N., Koutika, L.S. and Meerts, P. 2006. Effects of the invasive plant *Solidago gigantea* on soil phosphorus. *Biol. Fertil. Soils.* **42**: 481-489.

Chen, C.R., Condron, L.M., Davis, M.R., Sherlock, R.R. 2003. Phosphorus dynamics in the rhizosphere of perennial ryegrass (*Lolium perenne* L.) and radiate pine (*Pinus radiate.* Don). *Soil Biol. Biochem.* **34**: 487-499.

Culley, T.M., Weller, S.G., and Sakai, A.K. 2002. The evolution of wind pollination in angiosperms. *Eco and Evol.* **17**:361-369.

Dastan, S., Siavoshi, M., Ghanbaria, A., Yadi, R. and Nasiri, A.R. 2012. Application of Nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (*Oryza sativa* L.) *North of Iran. J. Agril. Sci*. **4**(6).

Diepenbrock, W. 2000. Yield analysis of winter oilseed rape (*Brassica napus* L.): a review. *Field Crops Res.* **67**: 35–49.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. 2 nd edition. John Willy and Sons, New York. pp. 28-102.

Gupta, R.R., Shukla, M. and Kumar, S. 2006. Effect of nitrogen and phosphorus on flowering of tuberose (*Polianthes tuberosa* L.). *Agric. Res. Info. Centre.* **32**(3): 539-541.

Gusewell, S., Zuberbuhler, N. and Clerc, C. 2005. Distribution and functional traits of *Solidago gigantea* in a Swiss lakeshore wetland. *Bot. Helv*. **115**: 63-75.

Jakobs, G., Weber, E. and Edwards, P.J. 2004. Introduced plants of the invasive *Solidago gigantea* (Asteraceae) are larger and grow denser than co-specifics in the native range. *Divers. Distrib.* **10**: 11-19.

Karuppaiah, P. and Krishna, G. 2005. Response of spacing and nitrogen levels of growth, flowering and yield characters of French marigold. *J. Ornam. Hort.* **8**(2): 96-99.

Khandker, M.M. 2003. Effect of rate and time of Phosphorus fertilizer application on growth and yield of rice. MS Thesis, Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh, p.163.

Lopez, L.R., Yunfei, M. and Semple, J.C. 2011. A multivariate study of *Solidago* subsect. *Junceae* and a new species in South America (Asteraceae: Astereae). *Novon.* **21**: 219-225.

Lu, H., Hai-gen, R., Tang, G., Yun-cai, C., Zhi-xia, G. and Wang, J. 2006. Evaluation of Harmfulness and Utility on Canada Goldenrod (*Solidago canadensis*). *J. Agril. Sci*. **4:**14-17.

Misra, H., Singh, A.K. and Singh, O.P. 2000. Effect of bulb size and spacing on growth and yield of tuberose . *Advan. P. Sci.* **13** (2): 563 – 566.

Mollah, M.S., Islam, S., Rafiuddin, M., Choudhury, S.S. and Saha, S.R. 1995. Effect of cormel size and spacing on growth yield of flower and corm of gladiolus. *Bangladesh Hort.* **23**:67-71.

Mustajarvi K., Siikamaki P., Rytkonen, S. and Lammi, A. 2001. Consequences of plant population size and density for plant pollinator interactions and plant performance. *J. Ecol*. **89**:80 –87.

Pandey, R.K. and Mishra, A. 2005. Effect of nitrogen, phosphorus and potassium on growth, flowering and seed yield in marigold cv. Pusa Narangi Gainda. *Prog. Hort.* **37**(2): 341-344.

Patel, K.A. and Desai, J.R. 2010. Influence of organic manures and chemical fertilizers on growth and yield attributes as well as economics of golden rod (*Solidago canadensis* L.) cv. Local yellow under south Gujarat conditions. *Int. J. Agric. Sci*. **6**(1): 253-258.

Patel, M.M., Parmer, P.B. and Parmer, B.R. 2006. Effect of nitrogen, phosphorus and spacing on growth and flowering in tuberose cv. Single. *J. Ornam. Hort*. **9**: 260-263.

Rahman, K.M.M., Chowdhury, M.A.K., Sharmeen, F., Sarker, A., Hye, M.A. and Biswas, G.C. 2011. Effect of Zinc and Phosphorus on Yield of *Oryza Sativa* (cv.BR-11). *Bangladesh Res. Pub.J*. **5**(4): 315-358.

Santos, B.M., Duskey, J.A., Stall, W.M., Bewick, T.A. and Shilling, D.G. 2004. Mechanism of interference of smooth pigweed and common purslance on Lettuce as influenced by phosphorus fertility. *Weed Sci*. **52**(1):78-82.

Semple, J.C., Rahman, H., Sbovski, S., Sorour, M.K., Kornobis, K., Lopez L.R. and Tong, L. 2015. A multivariate morphometric study of the *Solidago altissima* complex and *S. canadensis* (Asteraceae: Astereae). *Phytoneuron.* **10**:1–31.

Sharma, J.R. and Gupta, R.B. 2003. Effect of corm size and spacing on flowering and corm production in gladiolus. J. Ornam. Hort. New Seiies. **6**(4): 352-356.

Sharma, S.P. 1989. *Solidago*, In: Commercial Floriculture in India, p. 861.

Singh, S.R.P., Dhiraj, K., Singh, V.K. and Dwivedi, R. 2005. Effect of NPK fertilizers on growth and flowering of tuberose cv. Single. Haryana *J. Hort. Sci.* **34**(1/2): 84.

Singh, K.P. and Sangama. 2000. Effect of fertilizer on growth and flowering of tuberose (*Polianthes tuberosa*). *Applied Hort*. **2**(1): 54-55.

Siraz, A. and Maurya, K.R. 2005. Effect of spacing and corm size on growth, flowering and corm production in gladiolus. Indian J. of Hort. **62**(4): 419 42.

Stefanic, E., Puskadija, Z., Stefanic, I. and Bubalo, D. 2003. Goldenrod: a valuable plant for beekeeping in north-eastern Croatia. *Bee World*. **84**: 86-90.

Sultana, S., Khan, F.N., Haque, M.A., Akhter, S. and Noor, S. 2006. Effect of NPK on growth and flowering in tuberose. *J. Subtropical Agric. Res. Dev*. **4**(2): 111-113.

Tingare, S.S. and Patil, K.B. 2007. Effect of different spacing and nitrogen levels on growth and flower production of golden rod (*Solidago canadensts* L.). *Asian J. Soil Sci*. **2**(2): 98-100.

Weber, E. 2001. Current and potential ranges of three exotic goldenrods (*Solidago*) in Europe. *Conserv Biol*. **15**(1):122-128.

Weber, E. 2000. Biological flora of Central Europe: *Solidago altissima* L. *Flora* (Jena). **195(**2):123-134.

Wu, S., Yang, L., Gao, Y., Liu, X. and Liu, F. 2008. Multi-channel counter-current chromatography for high-throughput fractionation of natural products for drug discovery. *J. Chromat A*. **1180**(1-2):99-107.

Xiao, S., Shu-Yan, C., Lu-Qiang, Z. and Gang, W. 2006. Density Effects on Plant Height Growth and Inequality in Sunflower Populations. *J. Int. Plant Bio.* **48**: 513-519.

Yadav, P.K. 2007. Effect of nitrogen and phosphorus on growth and flowering of tuberose (*Pollianthes tuberosa* cv. Shringar). *Prog. Agric.* **7**(1/2): 189-191.

Yadav, S.K. and Tyagi, A.K. 2007. Effect of corm size and spacing on growth and flowering of gladiolus cv. Sylvia. Plant Arc. **7**(1). 343 344.

APPENDICES

Appendix I. Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period from May 2014 to October 2014

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2014	May	34.7	25.9	30.3	70	185	7.8
2014	June	35.4	22.5	28.95	80	577	4.2
2014	July	36.0	24.6	30.3	83	563	3.1
2014	August	36.0	23.6	29.8	81	319	4.0
2014	September	34.8	24.4	29.6	81	279	4.4
2014	October	26.5	19.4	22.95	81	22	6.9

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

Appendix II. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (meq)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

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

Appendix III . Effect of population density and phosphorus on plant height of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		50 DAT	70 DAT	90 DAT
Replication	2	3.421	3.113	2.863
Factor A	2	5.444*	8.167**	9.901*
Factor B	3	7.776**	12.764*	17.062*
AB	6	12.181*	15.823*	22.178*
Error	22	3.628	4.229	3.971

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix IV. Effect of population density and phosphorus on number of leaves of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		50 DAT	70 DAT	90 DAT
Replication	2	1.231	1.534	2.821
Factor A	2	5.183*	6.362**	2.282*
Factor B	3	10.326*	14.648*	7.241*
AB	6	7.144**	7.432*	11.514*
Error	22	1.066	2.1115	1.246

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix V. Effect of population density and phosphorus on number of side shoot per plant of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of number of side shoot plant^{-1}		
		70 DAT	80 DAT	90 DAT
Replication	2	1.323	0.526	0.364
Factor A	2	3.417*	4.207*	4.227**
Factor B	3	8.823**	9.524*	8.453*
AB	6	5.732*	7.325**	12.124*
Error	22	2.226	3.114	2.547

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix VI. Effect of population density and phosphorus on side shoot height of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of height of side shoot (cm)	
		70 DAT	90 DAT
Replication	2	1.697	0.483
Factor A	2	9.022*	7.861*
Factor B	3	18.639*	21.22**
AB	6	34.238*	6.019*
Error	22	3.189	4.720

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix VII. Effect of population density and phosphorus on spike length of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of spike length (cm)	
		70 DAT	90 DAT
Replication	2	1.114	0.627
Factor A	2	2.454**	5.613*
Factor B	3	11.347*	10.721**
AB	6	7.291*	6.568**
Error	22	4.324	3.621

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix VIII. Effect of population density and phosphorus on rachis length of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of rachis length (cm)	
		70 DAT	90 DAT
Replication	2	0.784	1.563
Factor A	2	5.264*	3.381**
Factor B	3	9.727*	8.646*
AB	6	12.163**	12.254*
Error	22	2.117	2.416

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix IX. Effect of population density and phosphorus on number of spikelet per spike of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of number of spikelet spike^{-1}	
		70 DAT	90 DAT
Replication	2	1.729	1.904
Factor A	2	6.323*	5.694**
Factor B	3	7.721**	13.256*
AB	6	14.297*	8.928*
Error	22	2.539	1.549

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix X. Effect of population density and phosphorus on number of spike per hill of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of number of spike hill^{-1}	
		70 DAT	90 DAT
Replication	2	1.188	3.151
Factor A	2	2.681*	8.374*
Factor B	3	3.755**	1.948**
AB	6	1.017*	0.766**
Error	22	2.085	2.061

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix XI. Effect of population density and phosphorus on spike per plot of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of number of harvested spike plot^{-1}		
		70 DAT	90 DAT	Total
Replication	2	1.334	2.404	0.232
Factor A	2	7.634*	6.454**	6.212**
Factor B	3	14.129*	12.329*	9.535*
AB	6	4.003**	1.206*	4.344*
Error	22	2.256	3.100	2.361

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix XII. Effect of population density and phosphorus on shelf life of golden rod at different days after transplanting

Sources of variation	Degrees of freedom	Mean square	
		Number of spike ha^{-1}	Shelf life (days)
Replication	2	20.194	0.531
Factor A	2	99.694*	3.414*
Factor B	3	374.667**	7.427*
AB	6	91.694*	1.277**
Error	22	25.588	1.284

** Significant at 0.01 level of probability * Significant at 0.05 level of probability

Appendix XIII. Production cost of golden rod per ha

A. Input cost (Tk. ha^{-1})

Treatment combination	Labour cost	Ploughing cost	Seedling Cost*	Water for plant establishment	Number of seedlings ha^{-1}	Manure and fertilizers				Insecticide/ pesticides	Sub-total (A)
						Cowdung	Urea	TSP	MP		
D_1P_0	26,000	15,000	62,500	5,000	125,000	12,000	2,400	0	1,920	7,000	131,820
D_1P_1	26,000	15,000	62,500	5,000	125,000	12,000	2,400	2,500	1,920	7,000	134,320
D_1P_2	26,000	15,000	62,500	5,000	125,000	12,000	2,400	3,125	1,920	7,000	134,945
D_1P_3	26,000	15,000	62,500	5,000	125,000	12,000	2,400	3,750	1,920	7,000	135,570
D_2P_0	24,000	15,000	41,667	5,000	83,333	12,000	2,400	0	1,920	7,000	108,987
D_2P_1	24,000	15,000	41,667	5,000	83,333	12,000	2,400	2,500	1,920	7,000	111,487
D_2P_2	24,000	15,000	41,667	5,000	83,333	12,000	2,400	3,125	1,920	7,000	112,112
D_2P_3	24,000	15,000	41,667	5,000	83,333	12,000	2,400	3,750	1,920	7,000	112,737
D_3P_0	22,000	15,000	31,250	5,000	62,500	12,000	2,400	0	1,920	7,000	96,570
D_3P_1	22,000	15,000	31,250	5,000	62,500	12,000	2,400	2,500	1,920	7,000	99,070
D_3P_2	22,000	15,000	31,250	5,000	62,500	12,000	2,400	3,125	1,920	7,000	99,695
D_3P_3	22,000	15,000	31,250	5,000	62,500	12,000	2,400	3,750	1,920	7,000	100,320

* Purchase cost per seedling = Tk. 0.50 $seedling^{-1}$

Appendix XIV. Production cost of golden rod per hectare (cont'd)

B. Overhead cost (Tk. ha^{-1})

Treatment combination	Cost of lease of land (Tk.14% of value of land cost/year)	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)]
D_1P_0	28,000	6,591	11,187	45,778	177,598
D_1P_1	28,000	6,716	11,362	46,078	180,398
D_1P_2	28,000	6,747	11,406	46,153	181,098
D_1P_3	28,000	6,779	11,450	46,228	181,798
D_2P_0	28,000	5,449	9,589	43,038	152,025
D_2P_1	28,000	5,574	9,764	43,338	154,825
D_2P_2	28,000	5,606	9,808	43,413	155,525
D_2P_3	28,000	5,637	9,852	43,488	156,225
D_3P_0	28,000	4,829	8,720	41,548	138,118
D_3P_1	28,000	4,954	8,895	41,848	140,918
D_3P_2	28,000	4,985	8,939	41,923	141,618
D_3P_3	28,000	5,016	8,982	41,998	142,318

Appendix XV. Map showing the experimental sites under study

☆ **The experimental site under study**