EFFECT OF SOWING DEPTH AND POPULATION DENSITY ON GROWTH AND YIELD OF WHEAT

BY

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A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2007

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF SOWING DEPTH AND POPULATION DENSITY ON GROWTH AND YIELD OF WHEAT"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY,** embodies the result of a piece of bona fide research work carried out by **JHILMIL ROY**, Registration No. **27433/00644** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 27/6/07
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENT

First of all, the author would like to express her sincere and deepest sense of gratitude, to Almighty God for without His Devine blessings it would not have been possible for the author to undertake and finish this task of experiment and compile the thesis paper.

The author wishes to express her heartfelt gratitude to Dr. Parimal Kanti Biswas, Professor and Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant supervision right from the setting of the experiment and his valuable suggestions, scholastic guidance, continuous inspiration, constructive comments and immense help for writing this manuscript from its embryonic stage.

The author expresses her sincere appreciation, respect and immense indebtedness to the respected co-supervisor Dr. Md. Hazrat Ali, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express her deepest respect to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for the valuable teaching, co-operation and inspiration during the course of this study and research work. In this context, the author likes to mention the name of Mr. Tuhin Shuvra Roy, Assistant Professor, SAU, who helped her taking the photographs of the crop field. The author also wishes to express her cordial thanks to the departmental and field staffs for their active help during the experimental period.

The author feels much pleasure to convey her profound thanks to her friend Lalita Rani Roy for her heartiest assistance in her research period. The author would like to express cordial thanks to Qazi Nasim Ahmed, Lecturer, SAU, for his encouragement to complete this thesis. The author would also wishes to express cordial thanks to relatives and well-wishers for the countless blessings, spiritual support and sacrifice throughout her academic life.

Lastly the author gratefully acknowledges her indebtedness to her beloved father Prof. Nalini Ranjan Roy and mother Joyanti Roy for their constant support, inspiration, blessings and sacrifice in all the way of life and also to her younger sisters Bulbul Roy and Monisha Roy to support her in all the situations of life. The author would like to express her boundless respect, gratitude and thanks to her husband Tuhin Sarkar for his inspiration, sacrifice and moral support to complete this study.

EFFECT OF SOWING DEPTH AND POPULATION DENSITY ON GROWTH AND YIELD OF WHEAT

ABSTRACT

A field experiment was conducted at the agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the Rabi season from November 2006 to March 2007 with the objectives to find out the influence of sowing depth and population density on growth and yield of wheat. The experiment was carried out in split-plot design with three replications having three sowing depths viz. 2 cm, 4 cm and 6 cm in main plot and 6 population densities viz. 100 seeds m^{-2}, 200 seeds m^{-2}, 300 seeds m^{-2}, 400 seeds m^{-2}, 500 seeds m^{-2} and 600 seeds m^{-2} in the sub plot. Result showed that sowing depth had significant influence on plant height at 30 DAS, weight of dry matter at 60 DAS, number of spikes m^{-2}, length of spike, number of grains $spike^{-1}$, grain yield and straw yield. Population densities had significant effect on plant height at 30 DAS, weight of dry matter at 30 DAS, number of spikes m^{-2}, length of spike, number of grains $spike^{-1}$, grain yield, straw yield and harvest index. The result also revealed that 4 cm sowing depth showed best performance in case of grain and straw yield. The highest grain yield (3.01 t ha^{-1}) and straw yield (6.26 t ha^{-1}) was obtained from 4 cm sowing depth. Highest grain yield (3.36 t ha^{-1}) was also produced from 300 seeds m^{-2} treatment, whereas, 100 seeds m^{-2} treatment produced the lowest grain yield (2.29 t ha^{-1}). The highest straw yield was observed with 400 seeds m^{-2} and the lowest from 100 seeds m^{-2}. The highest harvest index was recorded with 100 seeds m^{-2}. Among the interaction treatments, the sowing depth of 2 cm and 300 seeds m^{-2} produced the highest grain yield of 3.72 t ha^{-1}.

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1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second important cereal crop of Bangladesh. It is the leading cereal crop which ranks first both in area (21360 thousand hectares) and production (576317 thousand metric ton) of the world (FAO, 2000). Wheat is grown across a wide range of environments around the world. More lands are devoted world-wide to the production of wheat than to any other commercial crop. Wheat is cool-loving crop and adopted for cultivation in regions with cooler climatic conditions. Its production is concentrated between latitudes 30° and 60° N and 27° and 40° S (Nuttonson, 1955). But wheat flourishes in many different agro-climatic zones.

Bangladesh lies in the warmer part of the world and wheat is grown in the winter or cold season of the country. In consideration of the facts that growing of wheat in a location is decided by the temperature limits of 20° and 25°C (Ray and Nathan, 1986) and its grain growth and development depend on temperature range of 15°/10°C to 18°/15°C (Thorne *et. al.,* 1968), the best time of sowing of wheat in Bangladesh is the second half of November that needed around 105 days to complete its life cycle.

About one-third people of the world live on wheat. It is a staple food for about one billion in as many as 43 countries and provides about 20% of total food calories. It contains carbohydrate (78.1%), protein (14.7%) minerals (2.1%), fat (2.1%) and considerable proportion of vitamins (Peterson, 1965). Wheat contains about 12.1% protein on an average which is only 8.29% in rice (Mattern *et al.*, 1970). In the rice based cropping systems like Bangladesh, wheat is considered as the second most important cereal crop (Raazzaque and Hossain, 1990). Wheat is terribly under populated in our country. The low yield of wheat may be due to various factors such as lack of good quality seed, untimely seeding, low fertilization, seed rate, sowing techniques including sowing depth, irrigation scheduling etc.

Poor yield of wheat is resulted not only from poor seed quality but also from poor stand that results from broadcasting, dry seeding and bird damage prior to emergence. Sowing depth significantly influenced the seedling emergence and vigor index. Seeding depth contributes greatly to crop's stand establishment. Depth of seeding is also important for wheat, especially for germination, seedling emergence and uptake of nutrients which are influenced by moisture content of soil (Harbir *et al.,* 1991). Depth of seeding also affects the yield of wheat (Schmidt and Belford, 1994). In Bangladesh, wheat generally germinates with normal soil moisture conditions. A preliminary survey of farmer's planting practices of wheat in central part of Bangladesh showed that in the seedbed most seeds are placed beyond 8 cm of plough zone. In most cases it is found that upper layer of the soil dry quickly after land preparation. In that situation the seeds which fall on shallower depths are at risk of germination due to less imbibitions and seed soil contact. The risk can be avoided by sowing seeds at optimum depth that will ensure optimum plant stand establishment.

Establishment of plant population through optimum seed rate is another important factor for securing good yield of wheat. Seed rate was found to be influenced yield and yield contributing characters of wheat (Singh and Singh, 1987). Optimum plant density produces optimum number of plant per unit area resulting better yield contributing characters leading to better grain and straw yields of wheat (Singh, 1992). As the winter is very short in Bangladesh, crop can not attain proper vegetative growth. Hence getting increased ear population through increased tillering is remote but it could possibly be achieved through increased seed rate. But higher seed rate than the recommended one generally increases plant population resulting intra- crop competition thereby affecting the yield. Tiller mortality is greater at high planting density, and the number of fertile spikelets per spike, along with the yield components are mostly affected by planting density (Saradon *et al.,* 1988). Decreasing the planting density increases the amount of photosynthetic assimilation and provides a canopy structure which gives increased physiological activities after anthesis leading to a decreased rate of photosynthesis, increased total photosynthetic assimilation and increased sink effect on grain yield (Zhenhua and Yuyog, 1995). On the other hand, lower seed rate may reduce the yield drastically. Population densities significantly affect the yield of wheat. Optimum plant population ensures proper growth of the aerial and underground part of the plant through efficient utilization of solar radiation, nutrient uptake as well as air, space and water.

Because of these reports about the effect of sowing depth and population density on wheat, an experiment was performed with the following objectives:

1. to study the influence of different sowing depths on growth and yield of wheat.

2. to study the effect of different population density on growth and yield of wheat.

3. to determine the interaction effect of sowing depth and population density on the performance of wheat.

2. REVIEW OF LITERATURE

The effect of plant density and sowing depth on growth and yield of wheat has been studied under different ecological situations over the world. To get clear understanding on this subject some of the relevant research works are reviewed in this chapter.

2.1 Effect of sowing depth

2.1.1 Plant height

Silva (1991) reported that wheat cv. Candeias when sown at 3.5, 7.0, 10.5 or 14.0 cm soil depth showed grain yield of 5.25 - 5.86 t ha^{-1}, 1000 grain weight 39.2 - 40.2 g, and plant height which were not significantly affected by sowing depth.

Shahbaz *et al.* (1988) conducted a field trial in 1982 on a moderately calcareous silty clay loam soil at Islamabad where wheat cv. C-518 and C-591 (both tall) and Punjab -81 and Lyallpur-73 (both semi dwarf) were separated into 2 grades by size and sown at depths of 5 or 10 cm. It was found that seed size had no effect on seedling emergence, plant height and grain yield.

2.1.2 Number of spikes m^{-2}

Amin *et al.* (2004) conducted an experiment to test different sowing depth of wheat. Increasing the seeding depth more than 4 cm spike m^{-2} was significantly reduced. This was mainly due to the reduced emergence, which ultimately caused the lowest number of plants m^{-2}. The emergence percent was highest in 2 cm seeding depth, but total number of spike was lesser than that of 4 cm depth.

Wajid *et al.* (1997) evaluated wheat cultivars Pirsabak-85, Khyber-87, Pirsahak-91 and Kaghan-93 at sowing depths of 5 and 9 cm at Peshwar, Pirsabak and Jamra during 1994-95 and found that Khyber-87 had the highest spikes m^{-2} (183).

Silva (1991) sowed wheat cv.Candeias at 3.5, 7.0, 10.5 or 14.0 cm soil depth and found that the number of ears m^{-2} was not significantly affected by sowing depth. Plant density decreased and the number of ears $plant^{-1}$ increased significantly with increased sowing depth. The number of days to emergence increased with increased sowing depth. The number of days to flowering was greatest with sowing at 3.5 cm lest with sowing at 14 cm depth.

Loeppky *et al.* (1989) observed the effects of sowing depths on yield and plant survival in 14 field trials in winter wheat which was sown into standing stubble on several Saskatchewan soil types. The influence of sowing depth and date on winter growth and development was also investigated in a hand sown trial on conventional summer fellow. Increases in sowing depth as small as 17 mm resulted in significantly deeper crown placement and delayed plant emergence. Delayed deep sowing resulted in reduction in the numbers of tillers plant^{-1} and fewer ear m^{-2} of row in the following year.

2.1.3 Number of grain spike^{-1}

Amin *et al.* (2004) conducted an experiment to test different sowing depth of wheat. Significantly higher number of grains spike^{-1} was recorded from 8 cm depth. Generally deeper the planting depth greater was the success. This was rather expected because lesser number of seedlings emerged from deeper planted seeds and sparsely populated plants had better growth.

Wajid *et al.* (1997) evaluated wheat cultivars Pirsabak-85, Khyber-87, Pirsahak-91 and Kaghan-93 at sowing depths of 5 and 9 cm at Peshwar, Pirsabak and Jamra during 1994-95 and found that grains spike^{-1} were maximum at Peshawar (39). Sowing depth of 5 cm gave highest grains spike^{-1} (38). Khyber-87 had the highest grains spike^{-1} (39).

Silva (1991) sowed wheat cv. Candeias at 3.5, 7.0, 10.5 or 14.0 cm soil depth and found that the number of grains ear^{-1} was not significantly affected by sowing depth. Plant density decreased and the number of ears plant^{-1} increased significantly with increased sowing depth.

2.1.4 Weight of 1000 seeds

Wajid *et al.* (1997) evaluated wheat cultivars Pirsabak-85, Khyber-87, Pirsahak-91 and Kaghan-93 at sowing depths of 5 and 9 cm at Peshwar, Pirsabak and Jamra during 1994-95 and found that cultivars planted at Pirsabak had the highest 1000-grain weight (41.22 g), Khyber-87 had the highest 1000-grain weight (41.71 g).

Silva (1991) sowed wheat cv. Candeias at 3.5, 7.0, 10.5 or 14.0 cm soil depth and found that the 1000 grain weight (39.2-40.2 g) was not significantly affected by sowing depth.

2.1.5 Grain yield

Amin *et al.* (2004) conducted an experiment to test different sowing depth of wheat. Increasing the seeding depth over 4 cm, spike m^{-2} was significantly reduced. This was mainly due to the less number of emergence percent, which ultimately caused the lowest number of plants m^{-2}. The emergence percent was highest in 2 cm seeding depth, but total number of spike was less than that of 4 cm. The number of spikes m^{-2} was less than the number of tillers m^{-2}. Significantly highest grain yield was obtained with 4 cm sowing depth and the lowest (4189 kg ha^{-1}) from 8 cm depth and they were significantly different. The result compare favorably with the finding of Al Amin *et al.* (1994) who observed that sowing deeper than 4 cm greatly reduced yield.

McLeod *et al.* (1996) conducted a factorial experiment with combination of two sowing depths (25cm vs. 50 mm), two row spacing (18 vs. 36 cm) and two sowing rates (30 vs. 60 kg ha^{-1}) to study plant establishment, grain yield and grain quality of winter wheat. They found that there was no significant difference due to sowing depth. Deep sowing reduced plant establishment to grain yield in only two of 11 sites when humid conditions prevailed. For winter wheat production in the semiarid prairie it was recommended that sowing depth be shallow (about 25 mm), sowing rate be 60 kg ha^{-1}.

Singh and Uttam (1994) reported that sowing 125 kg seed ha^{-1} at 5 cm depth gave the highest wheat yield on a saline-alkaline soil.

Das and Kashyapi (1992) conducted a field trial in 1988-89 on loamy soil at Kalyani, West Bengal where wheat cv. UP 262 was sown at 4, 8 or 12 cm deep and was howed 24+48 or 48+72 days after sowing. Grain yield was decreased by sowing 12 cm deep and was 3.58-3.70 t ha^{-1} with hoeing and 2.5 ton without hoeing.

Silva (1991) reported that wheat cv. Candeias when sown at 3.5, 7.0, 10.5 or 14.0 cm soil depth produced the grain yield of 5.25 - 5.86 t ha^{-1}.

Harbir *et al.* (1991) showed that wheat cv. WH 316, WH 291and WH 147 at 4 cm soil depths in a sandy loam soil at Hisar in 1985-86 and 1986-87 and observed that grain yield was highest in both cropping years in WH 316, and from sowing at 5.5 cm depth. Grain yield was strongly and positively correlated with percent emergence and seedling length. The optimum sowing depth was calculated to be 4.63-4.89 cm depending on cultivar.

Vedrov and Frolov (1990) observed a micro plot trial on chemozem soil with spring wheat cv. Dvulineinaya, Skala and Udarintsawith. The 1000 grain weight of 36 - 45, 30 - 38 and 22 - 26 g respectively were sown at depths of 3, 5, 7 and 9 cm. Grain yield decreased from 198 - 244 g m^{-2} at a sowing depth of 3 cm to 79 - 145g from seeds sown 9 cm deep. Reductions were more marked in the small seeded cv. Udarintsa.

Loeppky *et al.* (1989) observed the effects of sowing depths on yield and plant survival in 14 field trials in winter wheat that was sown into standing stubble on several Saskatchewan soil types. The influence of sowing depth and date on winter growth and development was also investigated in a hand sown trial on conventional summer fellow. Delayed deep sowing resulted in fewer ear/m^2 of row. Winter survival was significantly higher for shallow sown treatments in 4 of 7 trials that experienced differential winterkill. A significant yield advantage (11%) was observed with shallow sowing in 4 or 6 trials that escaped serious winter damage. In contrast, improved winter survival and/or yield advantages were never obtained with increased sowing depths.

Shahbaz *et al*. (1988) conducted a field trial in 1982 on a moderately calcareous silty clay loam soil at Islamabad where wheat cv. C - 518 and C - 591 (both tall) and Panjab - 81 and Lyallpur - 73 (both semi dwarf) were separated into 2 grades by size and sown at depths of 5 or 10 cm and found that seed size had no effect on seedling emergence, plant height and grain yield. Grain yields were much higher (76.5 g/plot) from sowing at 10 cm depth than at 5 cm (44.4g). Sowing at 10 cm depth also increased total emergence. Among cultivars, grain yields ranged from 48.8 g in C - 518 to 74.4 g in Lyallpur-73.

Jepsen (1985) reported that on an average sowing depth of 2-4 cm gave the highest yields in winter wheat and barley. Deeper sowing normally reduced yields and depths of 8-12 cm caused late emergence and a large yield loss.

During 1970-72, Borse and Mohajan (1980) reported that the yield components and average grain yields of wheat cv. Sonalika were increased from 2.92 - 3.51 t ha^{-1} with increase in N rates from 50 to 100 and 150 kg/ha, respectively and from 2.99 to 3.47 and 3.6 t/ha with increase in sowing rate from 50-100 and 150 kg/ha. Crops sown 4-5 cm deed gave higher yields (3.85 t/ha), than those sown 8-10 cm deep (3.31 t/ha).

Shaner *et al.* (1978) observed the effect of seeding depth on the yield and competitive ability of two wheat cultivars (Anza and Inia 66 R). Surface sowing resulted in poor establishment, though yield increased with increasing seed rate. Stands were satisfactory at the other sowing depths (2, 4 and 7 cm).

Singh (1970) conducted a two year field trials at Madras, India and result revealed that grain yields of 4041 and 4647 kg/ha were shown sowing seeds at depths of 2.5 and 6.0 cm respectively.

In a 3 year field trials with winter wheat cultivar, Spaldon and Derco (1969) recorded economically profitable yield at seeding depth of 3.5 cm.

2. 2 Effect of population density

2.2.1 Plant height

Dixit and Gupta (2004) conducted an experiment to investigate the effects of seed rates (100, 125 and 150 kg ha^{-1}) on the growth and yield of wheat cv. HUW-234in Varanasi, Uttar Pradesh, India during rabi 1995/96. They reported that increasing the seeding rate significantly increased the plant height.

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates on growth and yield of surface seeded wheat. They used three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1}. They reported that in case of plant height, there were no significant different among the seed rate.

An observation was taken by Arif *et al.* (2002) to study the effect of different sowing rates on yield and yield components of wheat cultivars (Inqilab-91 and Bakhtawar-92). They used four seed rates (50, 100, 120 and 150 kg ha^{-1}) in the experiment. Maximum plant height (97 cm) was recorded at sowing rates of 150 kg seeds ha^{-1}. Inaqilab-91 produced the highest plant height (97 cm).

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. He used three levels of planting density (500, 250 and 188 seeds m^{-2}) and concluded that planting density did not significantly influence plant height. The highest plant height was observed in density of 188 seeds m^{-2}.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing character of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. He reported that there was no significant effect in respect of plant height of wheat due to different seed rate.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 400, 500 and 600 seeds m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and they observed that there were no significant difference among the seed rates in case of plant height.

Gaffer and Shahidullah (1985) conducted an experiment at Mymensingh to study the effect of seed rates on the performance of wheat cv. Inia-66. They used three levels of seed rates such as 100, 140 and 180 kg seeds ha^{-1}. Plant height was significantly higher at 100 kg seeds ha^{-1} than the other rates.

2. 2. 2 Dry matter production

Nag *et al.* (1998) conducted an experiment during winter, 1994-95 at Regional Agriculture Research Station, Rahamatpur, Barisal to investigate the response on growth and yield of wheat to different seed rates. It appeared that increasing seed rate resulted in increased total dry matter in wheat. They also found that per plant dry matter production decreased with increasing the seed rate.

The effect of crop density (300, 450 and 600 seeds m^{-2}) on dry matter accumulation and distribution in spring triticale and spring wheat were studied by Nierobca (2002). At crop densities of 300 and 450 plants m^{-2}, spring triticale showed greater dry matter accumulation in shoots than spring wheat; however, at 600 plants m^{-2}, spring wheat exhibited greater dry matter accumulation in shoots than spring triticale. Spring wheat recorded greater dry matter accumulation in well developed shoots (4, 5 and 6 labels) than in non productive shoots (1, 2 and 3labels).

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 400, 500 and 600 seeds m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and they observed that dry matter production per plant was highest with 100 seeds m^{-2}.

Saradon *et al.* (1988) reported that wheat cv. Klein Toledo, San Agustin and Marcos Juarez where sown to give plant densities of 120-360 plants m^{-2} at Myanmar and found that at higher plant densities translocations of DM to the ear was greater than in plants grown at lower densities. Dry matter distribution at harvest was not affected by plant density.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plants m^{-2}) to find out the effect planting density on the growth and yield of wheat. They reported that DM production $plant^{-1}$ was higher at the lower plant densities.

2.2.3 Spike length

Dixit and Gupta (2004) conducted an experiment to investigate the effects of seed rate (100, 125 and 150 kg ha^{-1}) on growth and the yield of wheat and found that increasing the seed rate significantly reduced the spike length.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. Three levels of planting densities (500, 250 and 188 seeds m^{-2}) were used and noticed that planting density frequencies differed significantly in respect of length of spike of wheat.

Hossain (2002) conducted an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120, 130 kg seeds ha^{-1}) were used as an experimental material. In that experiment, seed rate exerted significant effect on spike length.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. Spike length varied significantly due to increasing seed rate. The longest spike of 8.98 cm was produced from the treatment where 75 kg seed ha^{-1} which was followed by 8.76 and 8.40 cm obtained from the seed rate of 100 and 125 kg ha^{-1}.

Torofder (1993) conducted an experiment to study the effect of seed rates on the performance of different high yielding varieties of wheat. Three seed rates (80, 100, 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study where the length of spike decreased with the increase of seed rate.

Gaffer and Shahidullah (1985) conducted an experiment at Mymensingh to study the effect of seed rates on the performance of wheat c. Inia-66. Three levels of seed rates such as 100, 140 and 180 kg seeds ha^{-1} were used in the study and reported the ear length increased significantly at 100 kg seeds ha^{-1} than at the other rates.

2.2.4 Weight of 1000 seeds

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. Three levels of planting density (500, 250 and 188 seeds m^{-2}) showed that planting density did not significantly influence the weight of 1000 grains. The highest weight was observed in density of 188 seeds m^{-2} and the lowest from 500 seeds m^{-2}.

Hossain (2002) conducted an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120, 130 kg seeds ha^{-1}) were used as an experimental material. In that experiment, seed rate exerted significant effect on 1000 seed weight.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seeds ha^{-1} and revealed that the lowest seed rate produced the highest 1000 grains weight.

Ahmed *et al.* (1995) studied on two cultivars using seeding rates from 40-120 kg seed ha^{-1} and revealed that 1000 grains weight decreased from 40.47 to 39.69 g with the corresponding seeding rates.

Ionescu (1994) worked with winter wheat cv. Albota and Fundulea-4 at 100-500 plants m^{-2} in rows (a) 12.5 and (b) 25 cm apart. He found that grain yield were higher in (b) than in (a). It was affected by plant density in (a) but decreased with increased in plant density in Albota and increased in Fundulea-4 in (b) and 1000 grain weight was unaffected there.

Torofder (1993) conducted an experiment to study the effect of seed rates on the performance of different high yielding varieties of wheat. Three seed rates (80, 100, 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study and found that 1000 grains weight decreased with the increase of seed rate.

Mahajan *et al.* (1991) conducted an experiment with three seed rates of 100,125 and 150 kg ha^{-1}. Grain yield increased with seeding rate and was highest with sprouted seed (av. 3.51 t/ha). The 1000 grains weight was highest (41 g) with 150 kg sprouted seeds ha^{-1}.

Kreft and Spiss (1988) also reported that 1000 grain weight reduced at the highest stand density.

Chatha *et al.* (1986) used 18.5, 37.0, 55.5, 74.0 and 92.5 kg seeds ha^{-1} as an experimental treatment and found that increasing seeding rate had no significant effect on 1000 grain weight.

Gaffer and Shaidullah (1985) conducted an experiment at Mymensingh to study the effect of seed rates on the performance of wheat cv. Inia-66. Three levels of seed rates such as 100, 140 and 180 kg seeds ha^{-1} were used and found that 1000 grains weight was significantly higher at 100 kg seeds ha^{-1} than at the other weight.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plants m^{-2}) to find out the effect of planting density on the growth and yield of wheat and reported that 1000 grain weight remained unaffected by reduction in plant population.

2.2.5 Grain yield

Dixit and Gupta (2004) conducted an experiment to investigate the effects of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and the yield of wheat cv. HUW-234 in Varanasi, Uttar Pradesh, India during rabi 1995/96 and reported that increasing the seeding rate significantly increased the grain yield.

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates on growth and yield of surface seeded wheat. Three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} were used and reported that use of 175 kg seeds ha^{-1} resulted in the highest grain yield.

A field study was undertaken by Volynkina and Volynkin (2003) in the Kurgan region to show the effect of planting density on the yield and grain quality of spring wheat. The highest grain yield was obtained at a sowing rate of 2-3 million seeds ha^{-1}.

An observation was made by Arif *et al.* (2002) to study the effect of different sowing rates on yield and yield components of wheat cultivars (Inqilab-91 and Bakhtawar-92). Four seed rates (50, 100, 120 and 150 kg ha^{-1}) were used in the experiment. The maximum grain yield (3346 kg/ha) was recorded at sowing rates of 150 kg seeds ha^{-1}.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. Three levels of planting density (500, 250 and 188 seeds m^{-2}) were used. Planting density significantly influenced the grain yield. It was found that the highest grain yield obtained from the optimum planting density of wheat (250 seeds m^{-2}).

Hossain (2002) conducted an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seeds ha^{-1}) were used as an experimental material. In that experiment, seed rate exerted significant effect on grain yield.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. 125 kg seed/ha produced the highest grain yield and 75 kg seed/ha produced the lowest grain yield and they differed significantly with each other.

Nag *et al.* (1998) conducted an experiment during winter, 1994-95 at Regional Agriculture Research Station, Rahamatpur, Barisal to investigate the response on growth and yield of wheat to different seed rates. It appeared that increasing seed rate resulted in increased total dry matter in wheat. Seed rate resulted in increase total dry matter plant dry matter and leaf area index but did not increased grain yield in wheat.

Ionescu (1994) observed with winter wheat cv. Albota and Fundulea-4 at 100-500 plants m^{-2} in rows (a) 12.5 and (b) 25 cm apart. The grain yield was higher in (b) than in (a). It was affected by plant density in (a) but decreased with increased in plant density in Albota and increased in Fundulea-4.

Torofder (1993) conducted an experiment to study the effect of seed rates on the performance of different high yielding varieties of wheat. Three seed rates (80, 100, 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study. Statistically similar yields were found with seed rate of 100 and 120 kg/ha.

Mishra (1993) carried out a field trial where 100, 125 and 150 kg seeds ha^{-1} were used as experimental treatment and got the average grain yields of 1.24, 1.37 and 1.28 t/ha respectively.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 400, 500 and 600 seeds m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and reported that grain yield was significantly highest with 400 seeds m^{-2}.

Endres and Joba (1989) reported that the grain yield of wheat was the highest (5.2 t/ha) with the closer row-to-row spacing (10 cm) and was lowest (3.3 t/ha) with the widest row-to-row spacing (40 cm). Yield increased from 3.5 t/ha with 150 plants m^{-2} to 3.8 t/ha with 450 plants m^{-2}. In the experiment wheat sown at 2.25, 4.50 and 6.75 million germinable seeds ha^{-1}. The highest grain yield was achieved at the highest sowing rate.

Talukdar *et al.* (2004) reported that seed rate affected the initial plant population, spike length, grains/spike, 1000 seed weight and grain yield significantly. The higher number of spikes m^{-2} was obtained with 100 kg seed rate ha^{-1} but there was no significant difference with 120 kg seed rate/ha seeded plot. Similar trends were also observed in case of grain yield and total biomass. The highest grain yield of 4.16 t/ha in 2001-2002 and 4.20 t ha^{-1} in 2002-2003 was observed at 100 and 120 seed rate/ha, respectively, in both the years there were no statistical difference between the seed rates.

Fazli *et al.* (2004) made a three years (1990-1991 to 1992-1993) study in Nowshera, Pakistan to determine the effect of sowing date, seed rate and weed control method on grain yield and yield components of bread wheat. Seed rate 100 kg/ha significantly increased grains/spike, 1000 grain weight and grain yield. The highest seed rates of 150 kg/ha produced the maximum number of spikes m^{-2} compared to others.

2.2.6 Straw yield

Pandey *et al.* (2004) performed an experiment to investigate the effect of seed rates on growth and yield of surface seeded wheat where three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} were used and reported that use of 175 kg seeds ha^{-1} resulted in the highest straw yield.

Dixit and Gupta (2004) conducted an experiment to investigate the effects of seed rate (100, 125 and 150 kg ha^{-1}) on the growth and the yield of wheat cv. HUW-234 in Varanasi, Uttar Pradesh, India during rabi 1995/96. Increasing the seeding rate significantly increased the straw yield and the highest straw yield was 150 kg ha^{-1}.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. Where three levels of planting density (500, 250 and 188 seeds m^{-2}) were used. Planting density significantly influenced the straw yield. It was found that the highest straw yield obtained from the optimum planting density of wheat (250 seeds m^{-2}).

Hossain (2002) conducted an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seeds ha^{-1}) were used as an experimental material. In that experiment, seed rate exerted significant effect on straw yield and highest straw yield was in 103 kg ha^{-1}.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing characters of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seed ha^{-1}. 125 kg seed/ha produced the highest straw yield.

Torofder (1993) conducted an experiment to study the effect of seed rates on the performance of different high yielding varieties of wheat. Three seed rates (80, 100, 120 kg ha^{-1}) and four varieties (Akbar, Barkat, Ananda and Kanchan) were included in the study. Yield of straw increased significantly with higher seed rates as compared to that with the lower seed rates. Paul (1992) noted that sowing rates (120,140 or 160 kg seed ha^{-1}) did not significantly affect grain or straw yield.

2.2.7 Harvest index

Panday *et al.* (2004) worked with three different levels of seed rate such as 125, 150 and 175 kg seed ha^{-1} and reported that harvest index was unaffected by the variation of seed rates.

Das (2002) conducted an experiment to evaluate the effect of planting density on the yield of wheat cv. Kanchan. Three levels of planting density (500, 250 and 188 seeds m^{-2}) were used. The highest harvest index was observed from the optimum planting density at 250 seeds m^{-2} and the lowest harvest index was found from 500 seeds m^{-2}.

Hossain (2002) conducted an experiment to evaluate the optimum seed rate and harvesting time for wheat to obtain maximum yield as well as quality seed. Three levels of seed rate (110, 120 and 130 kg seeds ha^{-1}) were used as an experimental material. In that experiment, seed rate exerted significant effect on straw yield and harvest index.

Mozumder (2001) performed an experiment to investigate the effect of different levels of seed rate on the yield and yield contributing character of wheat. Treatments of seed rate in that experiment were 75, 100, 125 and 150 kg seeds ha^{-1}. Harvest index significantly varied due to different seed rates. The highest harvest index was observed in seed rate at 125 kg ha^{-1}.

Roy and Biswas (1991) carried out an experiment with 100, 200, 300, 400, 500 and 600 seeds m^{-2} to study the effect of population on tillering, growth, yield components and yield of wheat and observed that harvest index increased up to 400 seeds m^{-2} and there after decreased.

Borojevic and Kraljevic (1983) examined wheat which was sown at the rate of 300, 500, 700 seeds m^{-2}. The number of plant produced was 12.7, 14.4 and 15.9 % respectively. Increasing the seeding rate reduced the harvest index significantly.

Bagga and Tomar (1981) conducted an experiment with three levels of planting densities (200, 250 and 300 plants m^{-2}) to find out the effect planting density on the growth and yield of wheat. The harvest index remained unaffected by reduction in plant population.

3. MATERIALS AND METHODS

A field experiment was conducted in Rabi season to study the effect of sowing depth and population density on the growth and yield of wheat. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, collection and analysis of different parameters.

3.1 Location

The experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka- 1207, during the period from November 2006 to March 2007.

3.2 Experimental site

The experimental field was located at 23°77' N latitude and 90°33' E longitude at an altitude of 9 meters above the sea level (BCA, 2004).The land was medium high and well drained. The map of experimental site is shown in Appendix i.

3.3 Soil

The soil of the experimental site belongs to the Agro-ecological zone of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belongs to "Nodda" cultivated series. The top soil is silty clay loam in texture. Organic matter content was very low (0.82%) and soil pH varied from 5.47-5.63.

3.4 Weather

Cold temperature and minimum rainfall is the main feature of the experimental site in Rabi season. The monthly total rainfall, average sunshine hour, temperature (Maximum and Minimum) during the study period (November to March) is shown in Appendix ii.

3.5 Variety

A modern variety of wheat Shatabdi (BARI Gom-21) was released by BARI in 2000 for cultivation throughout Bangladesh. The height of the plant ranges from 95-100 cm. It produces 5-6 tillers $plant^{-1}$. Leaves are light green and flag leaf is droopy and light green in color. Seeds are big and white in color. Weight of 1000-seed is 46-48 g. It takes about 105-112 days from sowing to harvest. It is resistant against leaf spot and rust. The average yield of this variety is 3.6-5 ton ha^{-1}.

3.6 Layout of the experiment

The experiment was laid out in split-plot design with three replications. The experimental unit was divided into three blocks. Blocks represented the replication. Each block was divided into three main plots in which different depths were assigned at random. Each main plot was further divided into six sub plots and different plant populations were allotted these at random. So, the total number of unit plots in the entire experiment was $3 \times 3 \times 6 = 54$. Size of each unit plot was $3m \times 3m = 9m^2$. The distance between sub-plot was 0.5m and block was 1m.

3.7 Experimental treatments

There were two sets of treatments in the experiment. The treatments were sowing depth and population density. They are shown in bellow:

A. Main plot:

Sowing depth (3):

I. 2 cm- D_1

II. 4 cm- D_2

III. 6 cm- D_3

B. Sub plot (6):

Population density (6):

I. 100 Plants m^{-2}- P_1

II. 200 Plants m^{-2}- P_2

III. 300 Plants m^{-2}- P_3

IV. 400 Plants m^{-2}- P_4

V. 500 Plants m^{-2}- P_5

VI. 600 Plants m^{-2}- P_6

3.8 Details of the field operations

The particular of the cultural operations carried out during the experimentation are presented below:

3.8.1 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought desirable fine tilth and leveled by repeated laddering. The visible larger clods were hammered to break into small pieces. After removing of weeds, stubbles and crop residues were cleaned from the land. The final ploughing and land preparation were done on November 9, 2006. The layout was done as per experimental design on November 11, 2006.

3.8.2 Fertilizer application

The field was fertilized with urea, triple super phosphate, muriate potash, gypsum and zinc sulphate at the rate of 264, 220, 168, 168 and 5.56 kg ha^{-1} respectively. The whole amount of triple super phosphate (TSP), muriate of potash (MP), gypsum Zinc sulphate and one third of urea were incorporated with soil at the time of final land preparation. The remaining urea was applied in two installments, at crown root initiation stage (20 days after sowing) and prior to spike initiation stage (55 days after sowing) as top dressing.

3.8.3 Collection and sowing of seeds

The wheat seeds (cv. Shatabdi) were collected from Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Ggazipur. At good tilth condition, furrows were made with hand rakes for sowing. Seeds were sown continuously in line on November 11, 2006 as per experimental treatment. The line to line distance was maintained 20 cm. After sowing, seeds were covered with the soil and slightly pressed by hand.

3.8.4 Weeding

Weeds infested the experimental plots. So two weedings were done manually at 25 and 55 days after sowing. During weeding the weeds identified were Kakpaya ghash (*Dactyloctenium aegyptium* L.), Durba (*Cynodon dactylon* L.), Arail (*Leersia hexandra*), Chelaghash (*Parapholis incurve* Linn), Mutha (*Cyperus rotundus* L.), Bathua (*Chenopodium album* L), Foskabegun (*Physalis beterophylls*) and Titabegun (*Solanum torvum*).

3.8.5 Irrigation

Two irrigations were applied at crown root initiation stage and heading stage at 20 and 55 days after sowing respectively. Excess water was drained out from the field.

3.8.6 Pest management

At 20 days after sowing the experimental plots were sprayed with Melethion 57EC at the rate of 2 ml litre^{-1} to control aphid. No infestation of disease was found. Rat attacked the crop at 1st week of February. Zinc phosphide was applied to control rat. A guard was appointed to protect the wheat grain from bird especially Parrots from mid February to harvest.

3.8.7 Harvesting and sampling

The crop was harvested at maturity on March 20, 2007. Samples were collected from different places of each plot leaving undisturbed middle seven rows in the centre and border rows. The selected sample plants were then tagged and carefully carried to the Agronomy field laboratory in order to collect data. Plants of central 4.2 m^2 were harvested plot wise, bundled and tagged. The crop bundles were sun dried by spreading those on threshing floor. The grains were separated from the plants by beating the bundles with wooden sticks. The grain and straw were dried again to a constant moisture and the weight were recorded and converted into t ha^{-1} basis.

3.9 Data Collected

1. Plant height (cm) at 30 DAS, 60 DAS, 90DAS and at harvest
2. Dry weight of plant at 30 DAS, 60 DAS and at harvest
3. Number of spikes/m^2

4. Spike length (cm)
5. Number of grains/spike
6. Weight of 1000 grains
7. Shelling percentage
8. Grain yield (t ha^{-1})
9. Straw yield (t ha^{-1})
10. Harvest index (%)

3.9.1 Plant height

Ten plants per plot was randomly selected during earlier growth stage of the crop from 25 cm linear rows which were measured at 30, 60, 90 DAS and at harvest. The height was measured taking base to the leaf/spike and the mean height was recorded.

3.9.2 Dry matter weight

The plants within 25 linear centimeters in a row were uprooted with the help of hand weeder and cleaned with water. Plants were oven dried at 80° until a constant weight was obtained. The dry weight of the plants were recorded in gram and converted into per hectare basis. Data were collected at 30, 60, 90 DAS and at harvest.

3.9.3 Number of spikes m^{-2}

Number of total spikes per square meter of each plot were counted and recorded.

3.9.4 Spike length

Ten spikes per plot were randomly selected from where spike length from the base of the spike to the tip of the spikelets were measured and recorded.

3.9.5 Number of grains spike^{-1}

The total number of grains from 10 randomly selected spikes per plot was counted and the mean values were recorded.

3.9.6 Weight of 1000 grains

Thousand seeds were counted from the seed sample and weight at about 12% moisture level by using an electric balance and recorded as per.

3.9.7 Shelling percentage

The shelling percentage was calculated from the weight of 10 spikes and only shell weights of 10 spikes were taken from each plot and the mean results were recorded. Shelling percentage were calculated by the following formula-

$$\text{Shelling percentage (\%)} = \frac{\text{Weight of shell}}{\text{Weight of spike}} \times 100$$

3.9.8 Grain yield

Yield of each sample plot was measured after threshing, proper drying (12% moisture level) and cleaning and values were converted into ton ha^{-1}.

3.9.9 Straw yield

Straw weight of each plot was measured after threshing & drying and converted into ton ha^{-1}.

3.9.10 Harvest index

Harvest index (%) was determined by dividing the economic (grain) yield from the harvest area by the total biological yield (grain + straw) of the same area.

$$\textbf{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.10 Statistical analysis

The means for all collected data were calculated and the analyses of variance for all characters were performed. The collected data were analyzed by IRRISTAT software (Verson 4.0). The mean differences were analyzed by least significant difference (LSD) test.

4. RESULTS AND DISCUSSION

4.1 Plant height (cm) at different days after sowing

4.1.1 Effect of sowing depth

The plant height of wheat was significantly influenced by sowing depth at 60 days after sowing, but it was insignificant at 30 and 90 days after sowing and at harvest (Table 1).

At 30 DAS, the maximum plant height (31.33 cm) was obtained at 6 cm sowing depth and the minimum plant height (28.31 cm) was obtained at 4 cm depth though there was no significant difference among them. At 60 DAS the sowing depth showed significant different in plant height. The highest plant height (66.32) was observed at 2 cm sowing depth and the shortest plant height (58.44 cm) was recorded at 6 cm sowing depth (Table 1). Vedrov and Frolov (1990) reported that epicotyle length increased and plant height decreased with increasing sowing depth. At 90 DAS and at harvest, there was no significant difference in plant height. At 90 DAS the maximum plant height (93.27 cm) was observed at 2 cm depth and the minimum plant height (87.76 cm) was at 6 cm depth. At harvest maximum plant height was 98.60 cm at 4 cm depth and the minimum height was recorded at 6 cm depth and the height was 97.71 cm. The effect of these treatments on plant height was similar over the growing season. Such opinion was also given by Azad (1999) who mentioned that depth of seeding failed to show any significant influence on plant height, because seeding depth only influenced the emergence of seedling. Silva (1991) reported that plant height was not significantly affected by sowing depth.

4.1.2 Effect of population density

The plant height of wheat was significantly influenced by population density at 30 days after sowing, but it was insignificant at 60 and 90 DAS and at harvest. In case of plant height at 30 DAS, it was revealed from Table 1 that the tallest plant height (31.54 cm) was obtained from 500 seeds m^{-2}. That was statistically similar with 300, 400, and 600 plants m^{-2}. The shortest plant height (26.91 cm) was obtained from 100 seeds m^{-2} (Table 1). This report was similar to the findings of Chatha *et al.* (1986) and Dixit *et al.* (2004) who reported that increase the seeding rate significantly increased the plant height. At 60 DAS the maximum (64.71 cm) and minimum (59.98 cm) plant height was recorded with 600 seeds m^{-2} and 200 seeds m^{-2}. At 90 DAS the maximum (94.95 cm) and minimum (83.80 cm) plant height was recorded with 600 and 400 seeds m^{-2} respectively. At harvest maximum plant height (99.35 cm) was recorded in 400 seeds m^{-2} and minimum height (97.56 cm) was recorded in 100 seeds m^{-2}. Partially similar opinion was given by Roy and Biswas (1991), Mozumder (2001), Das (2002) and Pandey (2004). Pandey (2004) stated that in case of plant height there were no significant different among the seed rate. Das (2002) reported that population density did not significantly influence plant height.

Table 1 Influence of sowing depth and population density on plant height at different growth durations

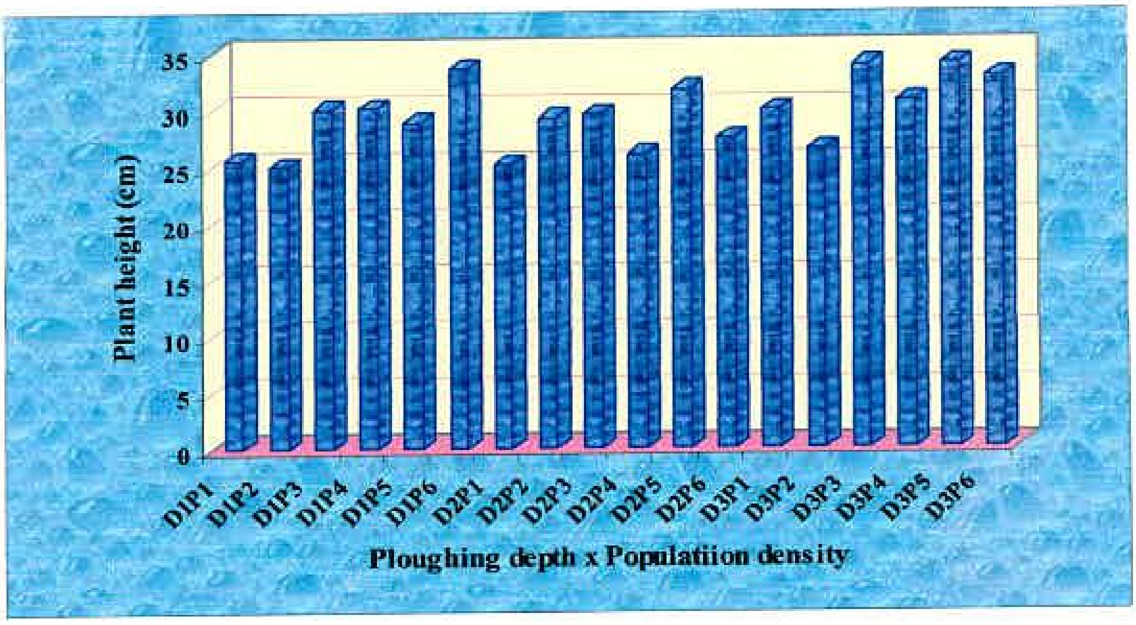
Treatments	Plant height (cm) at different growth durations			
Sowing depth (cm)	30DAS	60DAS	90DAS	At harvest
2	28.85	66.32	93.27	93.27
4	28.31	58.44	91.22	91.22
6	31.33	61.90	87.75	87.76
$LSD_{0.05}$	NS	4.066	NS	NS
Population density (No. of seeds m^{-2})				
100	26.91	61.46	93.14	97.56
200	26.93	59.98	89.56	97.43
300	31.20	64.08	90.53	98.31
400	28.93	61.58	83.80	99.35
500	31.53	64.50	92.51	97.97
600	31.45	64.71	94.95	97.61
$LSD_{0.05}$	4.60	NS	NS	NS
C.V.%	12.93	12.14	103.83	3.01

4.1.3 Interaction effect of sowing depth and population density

There was a significant variation in plant height observed due to interaction between sowing depth and population density at 30 and 60 DAS and at harvest but insignificant at 90 DAS.

At 30 DAS the tallest plant was obtained in 6 cm sowing depth and with 500 seeds m^{-2} (33.93 cm) which was statistically similar with all interactions except 2 cm sowing depth and 100 and 200 seeds m^{-2} and 4 cm sowing depth and 100 seeds m^{-2}

m^{-2} (Fig. 1). The shortest plant height was observed with 2 cm sowing depth and 200 seeds m^{-2}.

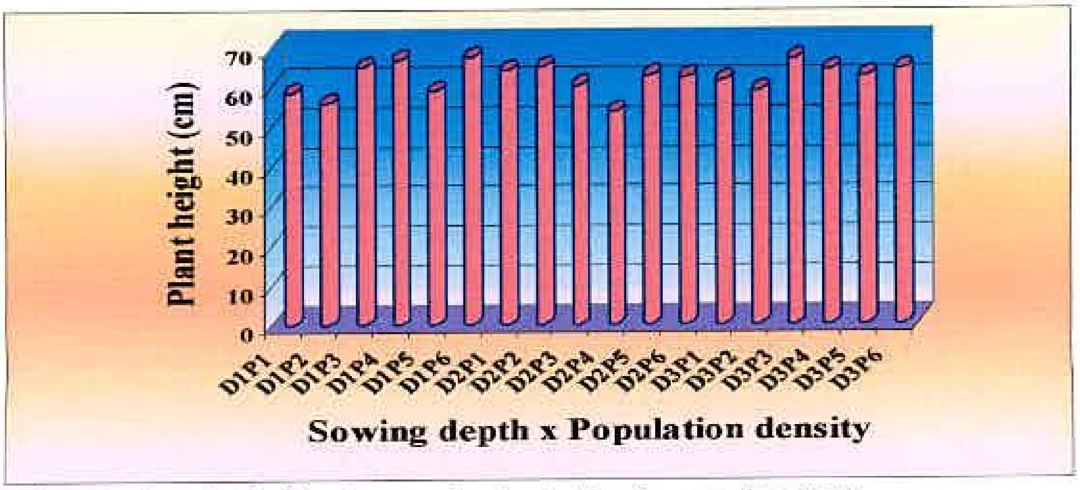


D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 1. Interaction effect of sowing depth and population density on plant height at 30 DAS ($LSD_{0.05}$ = 7.967)

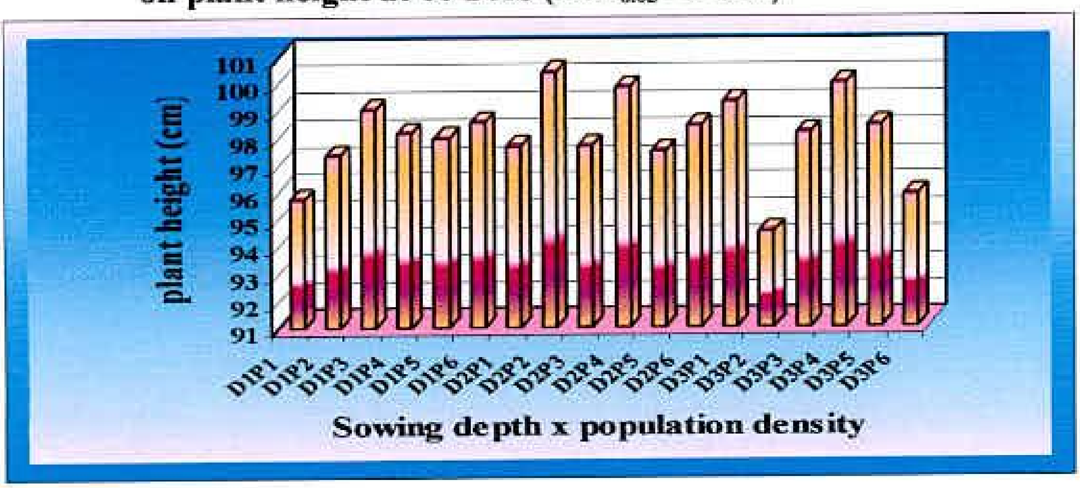
At 60 DAS the highest plant height (67.38 cm) was observed with 2 cm sowing depth and 600 seeds m^{-2} which was statistically similar in all interactions of sowing depth and population density except 2 cm sowing depth and 200 seeds m^{-2} and 4 cm sowing depth and 400 seeds m^{-2}. The lowest plant height (53.79 cm) was observed in 4 cm sowing depth and 400 seeds m^{-2} (Fig. 2).

At harvest the highest plant height (100.43 cm) was recorded with 4 cm sowing depth and 200 seeds m^{-2} and the lowest plant height (94.53 cm) was recorded with 6 cm sowing depth and 200 seeds m^{-2} (Fig. 3).



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 2. Interaction effect of sowing depth and population density on plant height at 60 DAS ($LSD_{0.05}$ = 9.959)



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 3. Interaction effect of sowing depth and population density on plant height at harvest ($LSD_{0.05}$ = 5.472)

4.2 Total dry matter production

4.2.1 Effect of sowing depth

Sowing depth showed significant effect on dry matter production at 60 days after sowing but it did not show significant effect on weight of dry matter at 30 days after sowing. At 30 DAS maximum (58.34 g) weight was recorded in 6 cm sowing depth and the minimum (39.78 g) weight was recorded with 4 cm sowing depth (Table - 2). At 60 DAS the highest (701.23 g) weight was recorded in 6 cm sowing depth and the lowest (524.90 g) weight was recorded with 4 cm sowing depth.

Table 2 Influence of sowing depth and population density on weight of dry matter at different growth duration

Treatments	Total dry matter accumulation at different growth durations ($g\ m^{-2}$)		
Sowing depth (cm)	30 DAS	60DAS	At harvest
2	56.5	570.78	691.67
4	39.78	524.90	908.33
6	58.34	701.23	654.63
$LSD_{0.05}$	NS	174.481	110.33
Population density (No. of seeds m^{-2})			
100	25.17	519.02	605.56
200	37.31	529.91	783.33
300	68.97	671.82	825.93
400	44.00	579.07	825.93
500	59.44	595.04	737.04
600	74.33	698.96	731.48
$LSD_{0.05}$	38.452	NS	156.04
C.V.%	66.08	49.37	21.66

4.2.2 Effect of population density

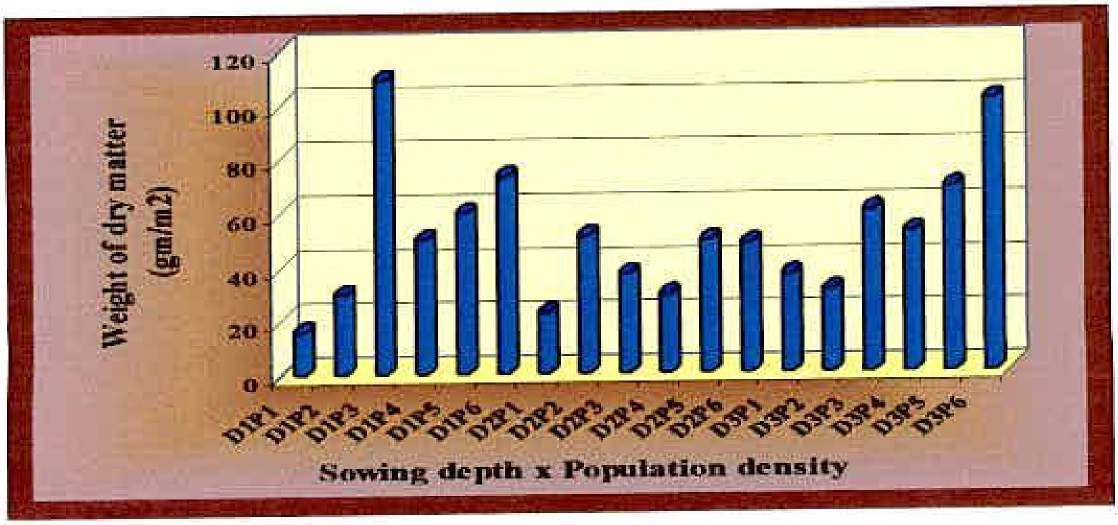
Population density showed significant influence on dry matter accumulation at 30 days after sowing and did not show significant effect at 60 DAS (Table 2). At 30 DAS the maximum (74.33 g) weight of dry matter was observed in 600 seeds m^{-2} and the minimum (25.17 g) weight of dry matter was observed at 100 seeds m^{-2}. At 60 DAS the highest weight was recorded with 600 seeds m^{-2} and the lowest weight was recorded with 100 seeds m^{-2}.

4.2.3 Interaction effect of sowing depth and population density

The combined effect of sowing depth and population density on total dry matter production was significant at 30 and 60 days after sowing. At 30 DAS the highest weight of dry matter m^{-2} (73.47 g) was recorded with 2 cm sowing depth and 300 seeds m^{-2} and the lowest weight (16.07 g) was observed with the interaction of 2 cm sowing depth and 100 seeds m^{-2} (Fig. 4).

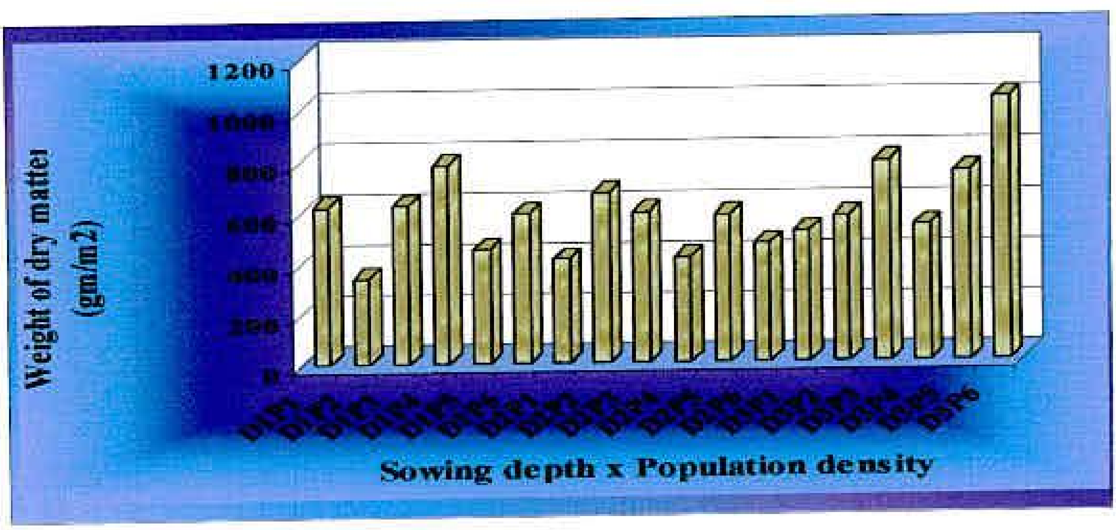
At 60 DAS the maximum weight of dry matter was found with the combined effect of 6 cm sowing depth and 600 seeds m^{-2}. The interaction of 2 cm sowing depth and 200 seeds m^{-2} gave the minimum weight (341.40 g m^{-2}) of dry matter at 60 DAS (Fig. 5).

The interaction effect of sowing depth and population density significantly influenced the weight of dry matter production at harvest (Fig. 6). The highest weight of dry matter (1055.56 gm m^{-2}) was recorded at 4 cm sowing depth and 400 seeds m^{-2} and minimum was recorded at 2 cm sowing depth and 100 seeds m^{-2}.



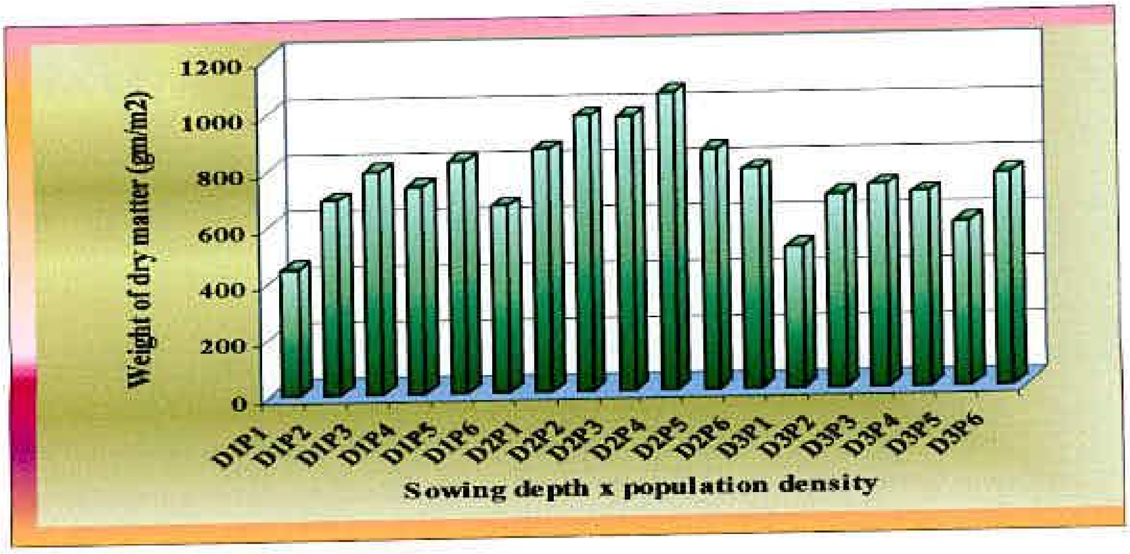
D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 4. Interaction effect of sowing depth and population density on weight of dry matter at 30 DAS ($LSD_{0.05}$ = 66.60)



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 5. Interaction effect of sowing depth and population density on weight of dry matter at 60 DAS ($LSD_{0.05}$ = 427.388)



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 6. Interaction effect of sowing depth and population density on weight of dry matter at harvest ($LSD_{0.05}$ = 186.389)

4.3 Number of spikes m^{-2}

4.3.1 Effect of sowing depth

The number of spikes m^{-2} was significantly influenced by depth of sowing. The highest numbers of spikes were obtained with 4 cm depth. The number of spikes meter $^{-2}$ with 4 cm depth was 322.50 and the lowest number of spikes m^{-2} (251.72) was observed with 6 cm depth (Table 2) The result was similar to the findings of Loeppky *et al.* (1989), Al-Amin *et al.* (1994), Rahman (2000), and Amin *et al.* (2004). Loeppky (1989) reported that delayed deep sowing resulted in the fewer ears/m^2. Rahman (2000) reported that 4 cm seeding depth produced more spikes m^{-2} than in other treatments. Amin *et al.* (2004) also stated that increasing the seeding depth more than 4 cm, spikes m^{-2} was significantly reduced.

4. 3. 2 Effect of population density

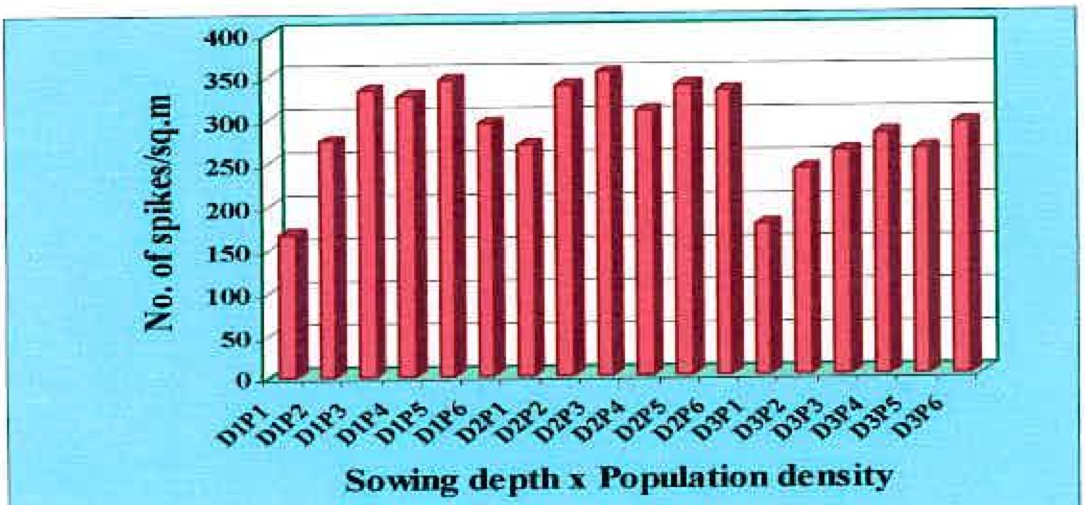
Population density had significant effect on no of spikes m^{-2} (Table 3). The significantly highest number (315.33) of spikes m^{-2} was observed with 300 plants m^{-2} which was similar to 200, 400, 500 and 600 seeds m^{-2} and the significantly lowest number (203.87) of spikes m^{-2} was observed with 100 seeds m^{-2}. Such opinion was given by Mazurek (1984), Roy and Biswas (1991), Fazli *et al.* (2004) who reported that the highest seed rate produced the maximum number of spikes m^{-2} compared to other seed rates. Roy and Biswas (1991) reported that number of ears m^{-2} was the highest with 600 seeds m^{-2} and the lowest with 100 seeds m^{-2}.

Table- 3. Number of spikes m^{-2} as influenced by sowing depth and population density

Treatments	Number of spikes meter^{-2}
Sowing depth (cm)	
2	290.06
4	322.50
6	251.72
$LSD_{0.05}$	30.386
Population density (No. of seeds m^{-2})	
100	203.78
200	284.00
300	315.33
400	304.86
500	315.11
600	305.44
$LSD_{0.05}$	42.972
C.V.%	15.49

4.3.3 Interaction effect of sowing depth and population density

The interaction effect of sowing depth and population density significantly influenced the number of spikes m^{-2}. It was found from Figure 6 that the interaction of 4cm sowing depth and 300 seeds m^{-2} gave the highest number of spikes m^{-2} (352.33). The interaction of 2 cm sowing depth and 100 seeds m^{-2} gave the lowest number of spikes m^{-2} (Fig. 7).



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 7. Interaction effect of sowing depth and population density on number of spikes m^{-2} ($LSD_{0.05}$=74.429)

4.4 Length of spike

4.4.1 Effect of sowing depth

The influence of sowing depth on length of spike was significant. The highest length of spike (10.26 cm) was recorded with 2 cm depth. The shortest spike

(9.80 cm) was recorded with 6 cm depth (Table 4). Azad (1999) reported that spike length was not affected significantly by seeding depth and highest spike length was obtained for 2.5 cm seeding depth whereas the lowest at 4.5 cm seeding depth.

4. 4 .2 Effect of population density

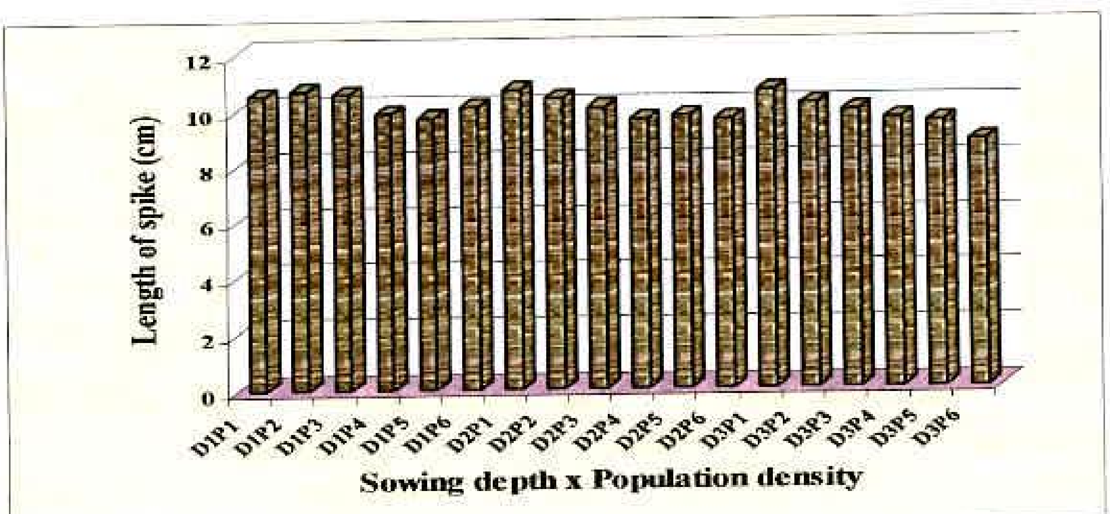
Length of spike was significantly influenced by population density of wheat. The maximum length of spike was 10.63 cm and it was observed in 100 seeds m^{-2}. The minimum length (9.52 cm) was recorded in 600 seeds m^{-2} (Table 4). The result was agreed with Wali and Wahab (1987), Torofder (1993), Fontes *et al.* (1997), Singh *et al.* (2002), Munir and Tawaha (2002) and Dixit and Gupta (2004). Munir and Tawaha (2002) found that spike length was negatively related to seeding rate. Singh *et al.* (2002) also reported that spike length decreased with increased seed rate. Dixit and Gupta (2004) found that increasing the seed rate significantly reduced the spike length.

4.4.3 Interaction effect of sowing depth and population density

Spike length showed significant variation due to the interaction between sowing depth and population density. The longest spike (10.7 cm) was obtained from the interaction of 2 cm sowing depth and 200 seeds m^{-2}. The shortest length of spike (8.80 cm) was recorded with 6 cm sowing depth and 600 seeds m^{-2} (Fig. 8).

Table 4. Influence of sowing depth and population density on length of spike

Treatments	Length of spike (cm)
Sowing depth (cm)	
2	10.26
4	10.05
6	9.80
$LSD_{0.05}$	0.314
Population density (No. of seeds m^{-2})	
100	10.63
200	10.44
300	10.20
400	9.73
500	9.67
600	9.52
$LSD_{0.05}$	0.445
C.V.%	4.55



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 8. Interaction effect of sowing depth and population density on length of spike ($LSD_{0.05}$= 0.770)

4.5 Shelling percentage

4.5.1 Effect of sowing depth

Sowing depth showed statistically similar effect on shelling percentage. Comparatively maximum (31.26) and minimum (30.06) shelling percentage was found with 4 cm sowing depth and 2 cm sowing depth respectively (Table 5).

4.5.2 Effect of population density

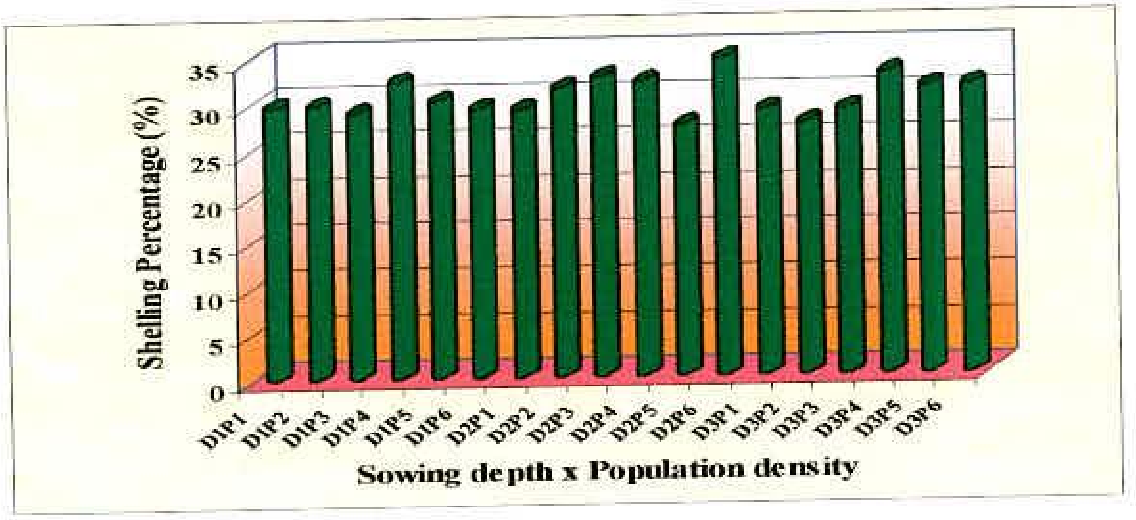
There was no significant influence of population density observed on the shelling percentage of wheat. The maximum shelling percentage (32.47 %) was recorded with 400 seeds m^{-2} and the minimum shelling percentage (29.27 %) was recorded with 100 seeds m^{-2} (Table 5).

Table 5. Effect of sowing depth and population density on shelling percentage

Treatments	Shelling percentage
Sowing depth(cm)	
2	30.06
4	31.26
6	30.18
$LSD_{0.05}$	NS
Population density (No. of seeds m^{-2})	
100	29.27
200	29.59
300	30.23
400	32.47
500	29.66
600	31.78
$LSD_{0.05}$	NS
C.V.%	10.58

4.5.3 Interaction effect of sowing depth and population density

Shelling percentage responded significantly due to the interaction of sowing depth and population density. Apparently from the Figure 9 it was found that the combination of 4 cm sowing depth and 600 seeds m^{-2} produced the highest shelling percentage (34.58 %) and the lowest shelling percentage was produced with 4 cm sowing depth and 500 seeds m^{-2}.



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 9. Interaction effect of sowing depth and population density on shelling percentage ($LSD_{0.05}$ = 4.404)

4.6 Number of grains spike^{-1}

4.6.1 Effect of sowing depth

Number of grains spike^{-1} was significantly influenced by depth of sowing. The maximum number (42.11 cm) of grains spike^{-1} was obtained with 2 cm depth of sowing. The minimum number of grains spike^{-1} (38.33) was recorded with 6 cm depth that was similar with 4 cm depth (Table 6). This result was disagreed with Silva (1991), Wajid *et al.* (1997), Rahman (2000), Munir and Tawaha (2002) and Amin *et al.* (2004). Amin *et al.* (2004) reported that significantly higher number of grains spike^{-1} was recorded from 8 cm depth. Generally deeper the planting depth greater was the seed size.

Table 6. Effect of sowing depth and population density on number of grains spike^{-1}

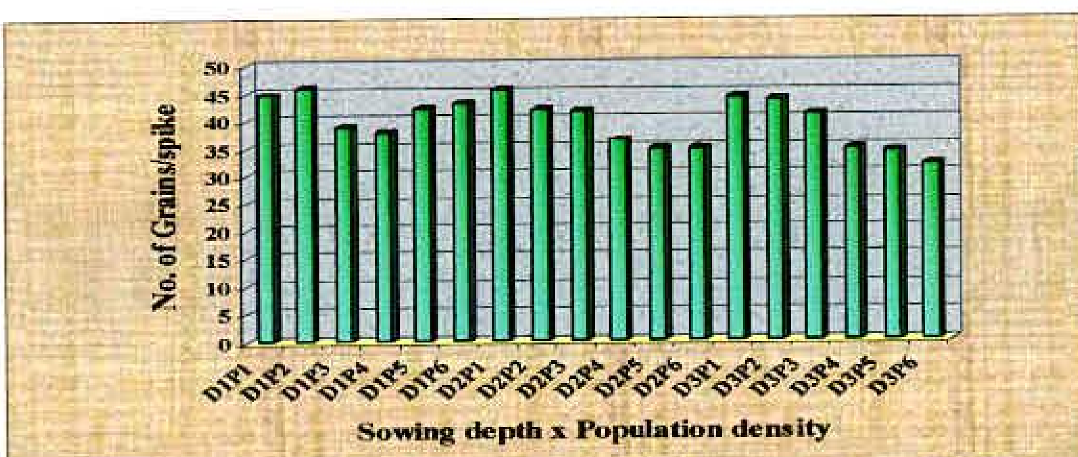
Treatments	Number of grains spike^{-1}
Sowing depth (cm)	
2	42.11
4	39.17
6	38.33
$LSD_{0.05}$	1.941
Population density (No. of seeds m^{-2})	
100	44.89
200	43.89
300	40.44
400	36.33
500	37.11
600	36.56
$LSD_{0.05}$	2.745
C.V.%	12.22

4. 6. 2 Effect of population density

Population density showed significant influence on number of grains spike^{-1} (Table 6).The maximum number of grains spike^{-1} was 44.89 observed with 100 seeds m^{-2} and it was statistically similar with 200 seeds m^{-2} (43.89). The minimum number of grains spike^{-1} (36.33) was recorded with 400 seeds m^{-2} which was similar with 500 and 600 seeds m^{-2} that produced 37.11 and 36.56 number of grains spike^{-1}respectively. Chatha *et al.* (1986), Sharar *et al.* (1978), Kreft and Spiss (1988), Roy and Biswas (1991),Singh *et al.* (2002) and Dixit and Gupta (2004) also observed the similar findings who stated that increasing the sowing rate significantly reduced the number of grains spike^{-1}. Kabir (2006) reported that seed rate had significant influence on number of grains spike^{-1}.

4.6.3 Interaction effect of sowing depth and population density

Number of grains spike^{-1} also responded significantly due to the interaction of sowing depth and population density (Fig. 10). The highest number of grains spike^{-1} (46) was observed with the interaction of 2 cm sowing depth and 200 seeds m^{-2}. The lowest number of grains spike^{-1} (32) was observed with the interaction of 6 cm sowing depth and 600 seeds m^{-2}.



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 10. Interaction effect of sowing depth and population density on number of grains spike^{-1} ($LSD_{0.05}$ = 4.754)

4.7 Weight of 1000 seeds

4.7.1 Effect of sowing depth

Sowing depth did not show any significant influence on weight of 1000 seeds of wheat. The maximum weight (39.11 g) of 1000 grain was recorded in 4 cm depth of sowing. The minimum weight (36.78 g) was obtained in 6 cm depth of sowing (Table -7). Azad (1999) reported that depth of seeding did not produce any significant variation in 1000 grain weight. The highest value of 1000 grain weight was obtained from 4.5 cm seeding depth and the lowest from 2.5 cm seeding depth.

4.7.2 Effect of population density

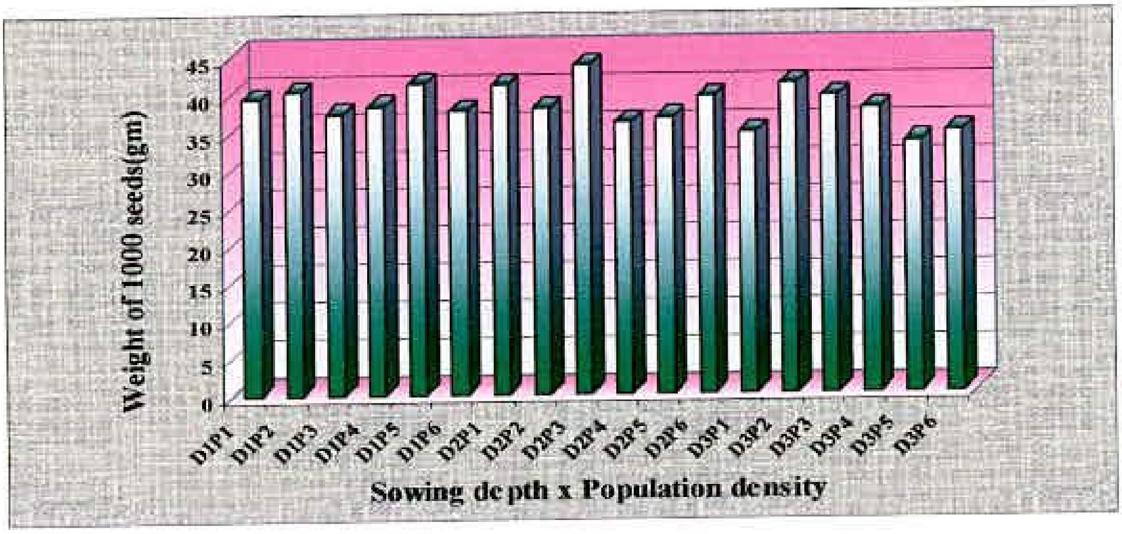
Population density had no significant effect on weight of 1000 seeds. The maximum weight of 1000 seeds (40.11 g) was found in 300 seeds m^{-2}, the second highest weight (39.78 g) was observed in 200 seeds m^{-2} and the lowest weight (37.11 g) was found with 500 seeds m^{-2} (Table 7). The result agreed with Bagga and Tomar (1981), Chatha (1986), Ali (1988), Roy and Biswas (1991), Das (2002), Kabir (2006) and Roy (2006) who reported that the 1000 grain weight did not differ significantly due to different seed rate of wheat.

4.7.3 Interaction effect of sowing depth and population density

There was significant interaction of sowing depth and population density on weight of 1000 seeds (Fig. 11). The highest weight of 1000 seeds (43.67 g) was observed with 4 cm sowing depth and 300 seeds m^{-2}. The interaction of 6 cm sowing depth and 500 seeds m^{-2} gave the lowest weight of 1000 seeds (33.33 g).

Table 7. Effect of sowing depth and population density on weight of 1000 seeds

Treatments	Weight of 1000 seeds (g)
Sowing depth (cm)	
2	39.06
4	39.11
6	36.78
$LSD_{0.05}$	NS
Population density (No. of seeds m^{-2})	
100	38.33
200	39.78
300	40.11
400	37.33
500	37.11
600	37.22
$LSD_{0.05}$	NS
C.V.%	12.18



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4 = 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6 = 600 seeds m^{-2}

Figure 11. Interaction effect of sowing depth and population density on weight of 1000 seeds ($LSD_{0.05}$ = 7.09)

4.8 Grain yield

4.8.1 Effect of sowing depth

Grain yield of wheat was significantly influenced by sowing depth. The highest grain yield (3.01 t ha^{-1}) was obtained with 4 cm seeding depth. The lowest amount of grain yield (2.51 t ha^{-1}) was obtained with 6 cm sowing depth (Table 8). The result was conformity with the findings of Al-Amin *et al.* (1994), Amin *et al.* (2004). Al-Amin *et al.* (1994), reported that sowing deeper than 4 cm greatly reduced grain yield. Amin *et al.* (2004) reported that significantly highest grain yield was obtained with 4 cm sowing and lowest from 8 cm depth.

Table 8. Effect of sowing depth and population density on grain yield

Treatments	Grain yield (t ha^{-1})
Sowing depth (cm)	
2	2.85
4	3.01
6	2.51
$LSD_{0.05}$	0.360
Population density (No. of seeds m^{-2})	
100	2.29
200	2.93
300	3.36
400	2.85
500	2.56
600	2.76
$LSD_{0.05}$	0.509
C.V.%	19.598

4. 8. 2 Effect of population density

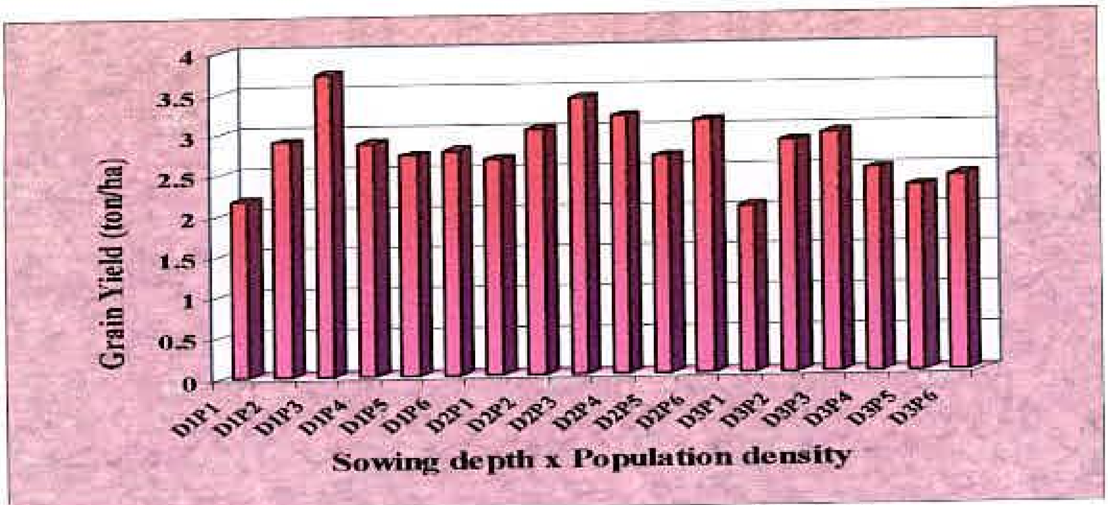
Grain yield was significantly influenced by population density. The significantly highest grain yield (3.36 t ha^{-1}) was obtained from 300 seeds m^{-2} and the lowest amount of grain yield (2.29 t ha^{-1}) was obtained from 100 seeds m^{-2} (Table 8). The findings of the present study was in agreement with Roy and Biswas (1991), Mozumder (2001), Hossain (2002), Das (2002), Dixit and Gupta (2004), Roy (2006) who reported that grain yield was significantly influenced by population density. Roy and Biswas (1991) stated that the highest grain yield obtained with 300-400 seeds m^{-2}. Roy (2006) found that 120 kg seeds ha^{-1} produced the highest grain yield and 80 kg seeds ha^{-1} produced the lowest grain yield. Tripathi and Chauhan (2000) reported that application of 150 kg ha^{-1} gave significantly lower yield than 125 kg ha^{-1} seed rate.

Ali (1980) reported a trend of decrease in the number of fertile tiller with the increase of seed rates which might be due to over crowding of population. Ballatore *et al.* (1975) also observed the similar effect of seed rates on wheat.

4.8.3 Interaction effect of sowing depth and population density

The interaction effect of sowing depth and population density significantly influenced the grain yield of wheat (Fig. 12). The highest grain yield (3.72t ha^{-1}) was found in 2 cm sowing depth and 300 seeds m^{-2}. The second (3.40 t ha^{-1}), third (3.18 t ha^{-1}) and fourth highest (3.12 t ha^{-1}) grain yield was observed with 4 cm sowing depth and 300 seeds m^{-2} population density, 4 cm sowing depth and

400 seeds m^{-2} and 4 cm sowing depth and 600 seeds m^{-2} respectively. The lowest grain yield (2.05 ton ha^{-1}) was obtained with 6 cm sowing depth and 100 seeds m^{-2}.



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 12. Interaction effect of sowing depth and population density on grain yield ($LSD_{0.05}$ = 0.883)

4.9 Straw yield

4.9.1 Effect of sowing depth

Sowing depth showed significant effect on straw yield. Significantly highest straw yield (6.26 t ha^{-1}) was recorded in 4 cm sowing depth. The lowest amount of straw was obtained with 6 cm sowing depth (Table 9). Amin *et al.* (2004) found highest straw yield in 4 cm depth and lowest in 6 cm depth.

Table 9. Effect of sowing depth and population density on straw yield

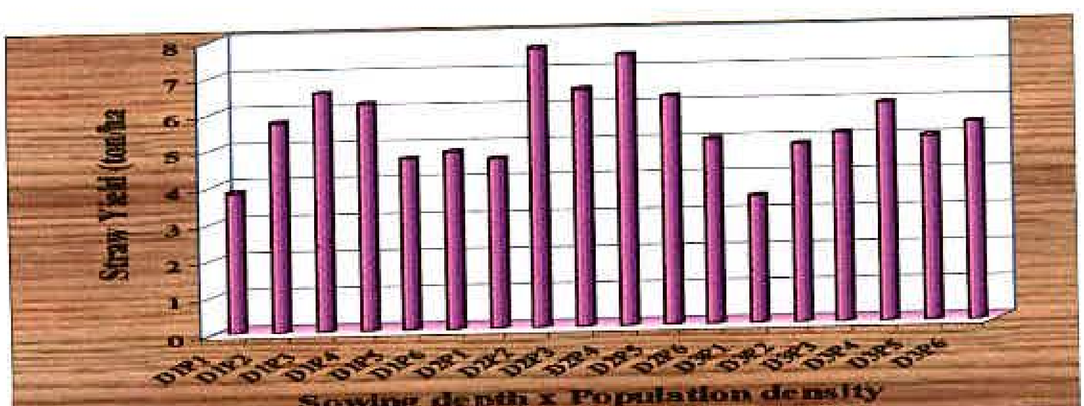
Treatments	Straw yield (t ha^{-1})
Sowing depth (cm)	
2	5.29
4	6.26
6	4.99
$LSD_{0.05}$	NS
Population density (No. of seeds m^{-2})	
100	3.96
200	6.09
300	6.06
400	6.55
500	5.32
600	5.10
$LSD_{0.05}$	0.874
C.V.%	16.40

4. 9. 2 Effect of population density

Population density had significant influence on straw yield of wheat. The significantly highest straw yield (6.55 t ha^{-1}) was observed with 400 seeds m^{-2}, the second (6.09 t ha^{-1}) was observed with 200 seeds m^{-2} and lowest straw yield (3.96 t ha^{-1}) was recorded with 100 seeds m^{-2}. Ali and Ahmed (1988), Torofder (1993), Thakur (1999), Das (2002), Hossain (2002) Dixit and Gupta (2004) and Roy (2006) found the similar results and reported that straw yield was significantly influenced by different seed rate. Roy and Biswas (1991) reported that straw yield was the highest with 500 seeds m^{-2}. Das (2002) stated that straw yield varied significantly due to planting densities and reported that maximum straw yield was recorded at optimum planting density of 250 seeds m^{-2}. Paul (1992) noted that sowing rates did not significantly affect straw yield.

4.9.3 Interaction effect of sowing depth and population density

The interaction effect of sowing depth and population density was found significant in respect of straw yield of wheat (Fig. 13). It was observed from Figure-13 that the highest straw yield (7.67 t ha^{-1}) was observed at 4 cm sowing depth and 200 seeds m^{-2}. It was statistically similar with 2cm sowing depth and 300 seeds m^{-2}, 2cm sowing depth and 400 seeds m^{-2}, 4cm sowing depth and 300 seeds m^{-2}, 4cm sowing depth and 400 seeds m^{-2}, and 4cm sowing depth and 500 seeds m^{-2} which produced 6.52 t ha^{-1}, 6.21 t ha^{-1}, 6.50 t ha^{-1}, 7.44 t ha^{-1}, and 6.26 t ha^{-1} respectively. The lowest amount of straw yield was produced with the interaction of 2 cm sowing depth and 500 seeds m^{-2}.



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth
P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 13. Interaction effect of sowing depth and population density on straw yield ($LSD_{0.05}$ = 1.514)

4.10 Harvest index

4.10.1 Effect of sowing depth

Sowing depths showed statistically similar effect on harvest index of wheat. Comparatively highest (34.83 %) harvest index was observed with 2 cm depth and lowest (34.78 %) harvest index was in 6 cm depth (Table 10).

Table 10. Effect of sowing depth and population density on harvest index

Treatments	Harvest index (%)
Sowing depth (cm)	
2	34.83
4	34.33
6	34.17
$LSD_{0.05}$	NS
Population density (No. of seeds m^{-2})	
100	37.00
200	33.67
300	36.56
400	30.67
500	33.33
600	35.44
$LSD_{0.05}$	4.656
C.V.%	13.93

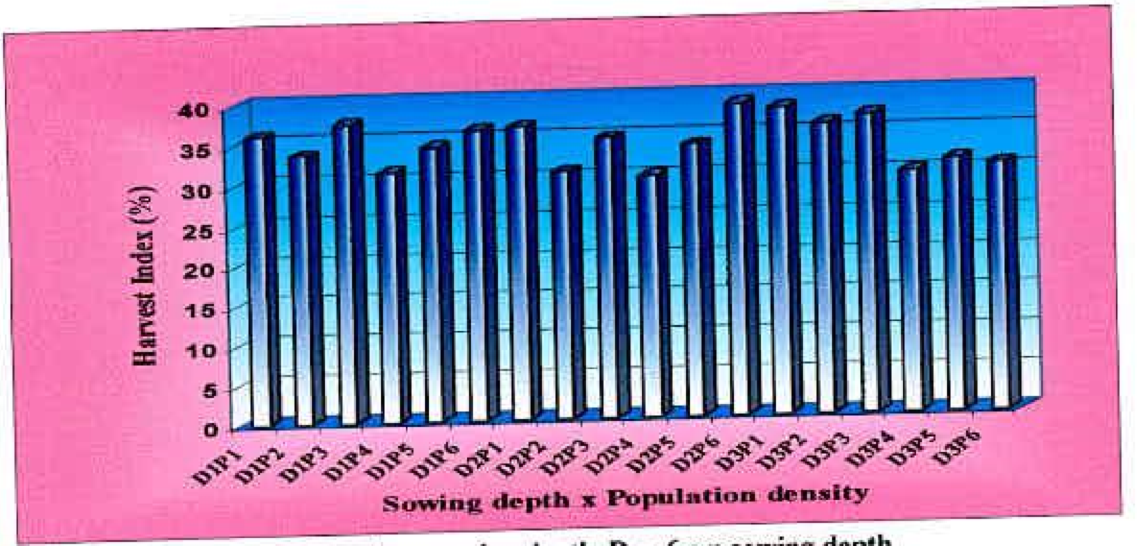
4. 10. 2 Effect of population density

Harvest index was significantly influenced by population density of wheat. The highest harvest index (37.00 %) was observed with 100 seeds m^{-2} which was similar with 200 seeds m^{-2} (33.67 %), 300 seeds m^{-2} (36.56%), 500 seeds m^{-2}

(33.33 %)and 600 seeds m^{-2} (35.44 %). The lowest harvest index was observed with 400 seeds m^{-2}. Borojevic and Kraljevic (1983), Roy and Biswas (1991), Mozumder (2001), and Hossain (2002) observed significant influence of population density on harvest index. Borojevic and Kraljevic (1983) reported that increasing the seeding rate reduced the harvest index significantly. On the other hand, Roy and Biswas (1991) reported that the highest harvest index was achieved with 300 – 400 seeds m^{-2}.

4.10.3 Interaction effect of sowing depth and population density

Significant variation was observed in harvest index due to the interaction of sowing depth and population density (Fig. 14). The highest harvest index (39.00%) was recorded in the interaction of 2 cm sowing depth and 600 seeds m^{-2}.



D_1 = 2 cm sowing depth, D_2 = 4 cm sowing depth, D_3 = 6 cm sowing depth P_1 = 100 seeds m^{-2}, P_2 = 200 seeds m^{-2}, P_3 = 300 seeds m^{-2}, P_4= 400 seeds m^{-2}, P_5 = 500 seeds m^{-2}, P_6= 600 seeds m^{-2}

Figure 14. Interaction effect of sowing depth and density on Harvest index ($LSD_{0.05}$ = 8.064)

5. SUMMARY AND CONCLUSION

The experiment was conducted at Agronomy field laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in the rabi season during the period from November 2006 to March 2007 to find out the influence of sowing depth and population density on growth and yield of wheat. The experiment included three sowing depths viz. 2 cm (D_1), 4 cm (D_2) and 6 cm (D_3) and six population densities viz. 100 (P_1), 200 (P_2), 300 (P_3), 400 (P_4), 500 (P_5) and 600 (P_6) seeds m^{-2} respectively.

The experiment was laid out in a split plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into three main plots in which sowing depths were applied at random. Each main plot was further divided into six sub plots and different plant populations were allotted there at random.

The data on crop growth characters like plant height and dry mater were recorded at different days after sowing. Plant height from 30 DAS to harvest (cm) and total dry matter accumulation at 30 DAS, 60 DAS and at harvest (g m^{-2}) were recorded. The different data like number of spikes m^{-2}, length of spike (cm), shelling percentage (%), number of grains spike^{-1}, weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) were recorded.

The collected data were compiled and analyzed to find out the statistical significance of experimental results. The analysis was done by using the software

IRRISTAT (Version 4.0, IRRI, Philippines). The means for all recorded data were calculated and the analyses of variance of all characters were performed. The mean differences were evaluated by least significant difference (LSD) test.

Results of the experiment showed that the depths had significant effect on plant height at 60 DAS, dry matter accumulation at 60 DAS, number of spikes m^{-2}, length of spike, number of grains $spike^{-1}$, 1000 grain weight, grain yield and straw yield. Population density showed significant influence on plant height at 30 DAS, weight of dry matter, length of spike, number of grains $spike^{-1}$, grain yield, straw yield and harvest index.

The highest plant height (98.60 cm) at harvest was recorded at 4 cm sowing depth and the shortest plant height (97.71 cm) was recorded with 6 cm sowing depth. The tallest (99.35 cm) and shortest (97.43 cm) plant height were recorded with 400 seeds m^{-2} and 200 seeds m^{-2} respectively at harvest. Interaction effect of 4 cm depth and 200 seeds m^{-2} was found most significant to produce highest plant height (100.43 cm).

The highest number of spikes m^{-2} (322.5) was produced in 4 cm sowing depth and lowest (273.94) in 6 cm sowing depth. The lowest spikes m^{-2} (203.78) and highest spikes m^{-2} (315.33) was produced from 100 and 300 seeds m^{-2} respectively. The interaction of 4 cm sowing depth and 300 seeds m^{-2} produced the maximum number of spikes m^{-2} (352.33).

The longest (10.26 cm) and shortest (9.80 cm) spike length was produced from 2 and 6 cm sowing depth respectively and in case of population density the longest

(10.63 cm) and shortest spikes (9.52 cm) was recorded from 100 and 600 seeds m^{-2}. The interaction of 2 cm sowing depth and 400 seeds m^{-2} produced the highest length of spike.

The highest (42.11) and lowest (38.33) number of grains $spike^{-1}$ was produced from 2 and 6 cm depths. The population density at 100 and 400 seeds m^{-2} produced the maximum (44.90) and minimum (36.33) number of grains $spike^{-1}$. The interaction of 2 cm depth and 200 seeds m^{-2} produced the maximum and 4 cm depth and 600 seeds m^{-2} produced the minimum number of grains $spike^{-1}$.

The 4 cm sowing depth produced the highest grain yield (3.01 t ha^{-1}) that was statistically similar with the grain yield of 2 cm sowing depth (2.85 t ha^{-1}). The 6 cm sowing depth produced the lowest amount of grain yield (2.51 t ha^{-1}). The 300 seeds m^{-2} produced the maximum grain yield (3.36 t ha^{-1}) which was similar with 200 and 400 seeds m^{-2}. 100 seeds m^{-2} produced the minimum grain yield (2.29 t ha^{-1}). The interaction effect of 2 cm sowing depth and 300 seeds m^{-2} produced the highest (3.72 t ha^{-1}) grain yield. The lowest grain yield was produced with the interaction of 6 cm depth and 100 seeds m^{-2}.

The maximum straw yield was produced from 4 cm sowing depth. The 2 cm and 6 cm sowing depth produced statistically similar straw yield. The 400 seeds m^{-2} produced the highest straw yield (6.55 t ha^{-1}). The interaction of 6 cm sowing depth and 100 seeds m^{-2} produced the lowest straw yield.

Statistically similar harvest index was observed in case of different sowing depths. The 100 seeds m^{-2} produced the highest harvest index and 400 seeds m^{-2} produced the lowest harvest index. The interaction of 4 cm sowing depth and 600 seeds m^{-2} produced the highest harvest index.

From the above discussions, it may be concluded that the higher yield could be obtained by applying 2-4 cm sowing depth and 300-400 seeds m^{-2}. However, to reach the specific conclusion and recommendation, more research work on sowing depth and population density should be done over different Agro ecological zones of Bangladesh.

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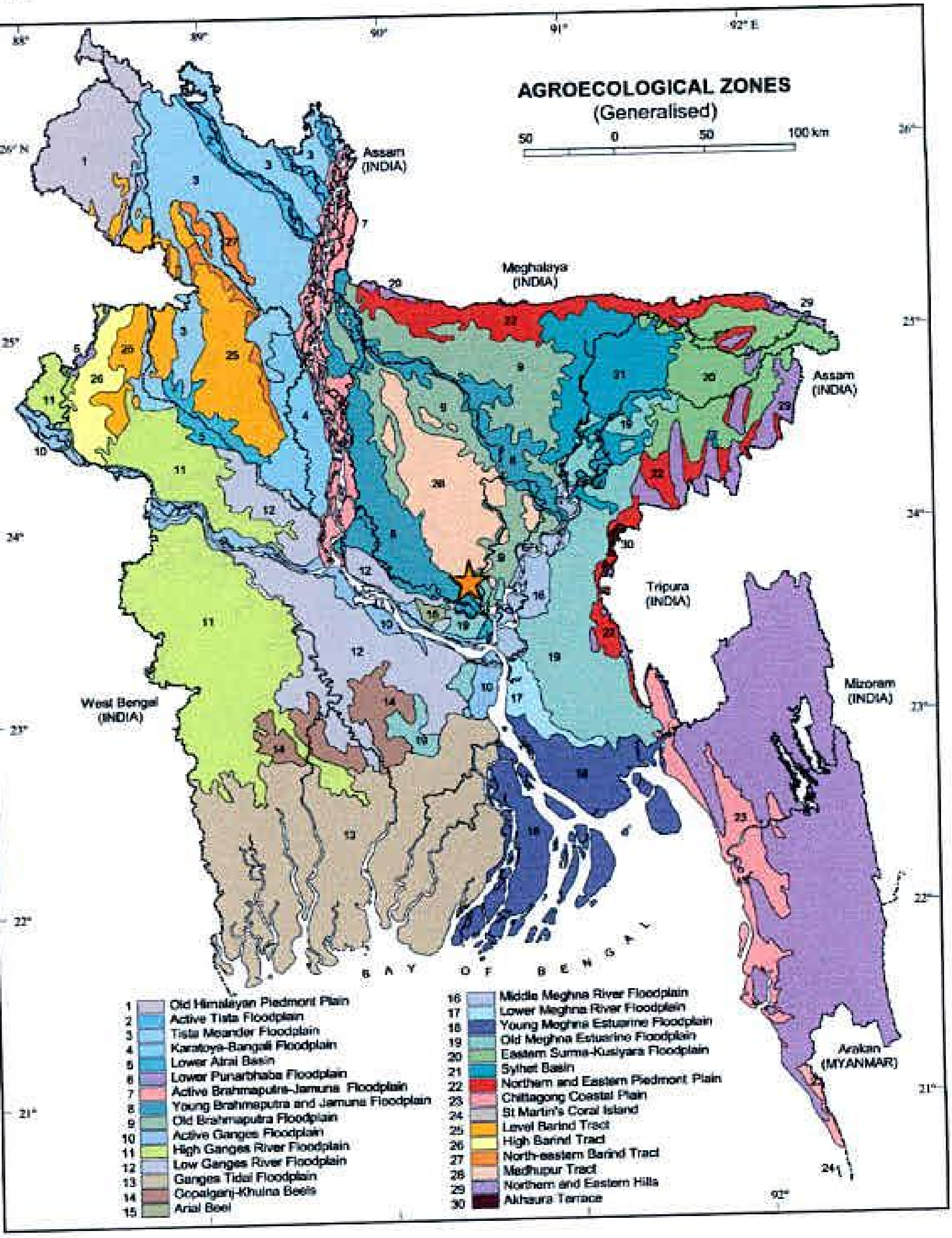
APPENDICES

Appendix I. Map showing the experimental site under study



★ **The experimental site under study**

Appendix II. Monthly average Temperature, Relative humidity, Total rainfall and Sunshine hour of the experiment site during the period from November 2006 to March 2007

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hr)
		Maximum	Minimum	Mean			
2006	Nov.	29.70	20.10	24.90	65	05	178.72
	Dec.	26.90	15.80	21.20	68	-	170.97
2007	Jan.	24.60	12.50	18.55	66	-	175.40
	Feb.	27.10	16.80	21.95	64	-	158.68
	Mar.	31.50	19.60	25.55	47	160	255.01

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

Appendix-III Mean square values for plant height and dry matter production at different days after sowing

Source of variation	Degrees of freedom	Mean square						
		Plant height				Dry matter production		
		30 DAS	60 DAS	90 DAS	At Harvest	30 DAS	60 DAS	At Harvest
Replication	2	46.4201	280.719	14801.1	42.4813	1808.87	205042	285098
Sowing depth (D)	2	46.4201	12.8483	12370.9	4.33486	1882.25	150651	338045
Error (a)	4	4.75963	22.6858	12852.1	34.2461	1618.59	9760.49	72134.8
Population Density (P)	5	43.9611	29.1703	13333.7	4.63228	3313.38	48378.4	61202.7
D × P	10	14.5335	57.0992	12013.8	8.73055	1159.77	87460.7	26508.2
Error (b)	30	22.8313	35.6742	11885.7	10.7716	1595.35	65697.2	26270.6
Total	53	23.6785	46.5084	12247.7	12.5327	1695.88	72412.1	54604.5

Appendix-IV Mean square values different crop characters of wheat as affected by sowing depth and population density

Source of variation	Degrees of freedom	Mean square					
		No. of spikes m^{-2}	Length of spike	Shelling percentage	No. of grains $spike^{-1}$	Weight of 1000 seeds	Grain yield
Replication	2	7338.80	.532106	7.34024	.0185186	.962963	1.53
Sowing depth (D)	2	22594.70	.956339	7.87273	70.9074	31.9074	1.20
Error (a)	4	5610.91	.815994	4.85925	22.5185	13.6852	0.65
Population density (P)	5	16525.80	1.86285	15.5023	130.996	16.1519	1.16
D × P	10	2078.14	.212541	10.4142	23.7296	21.7741	0.10
Error (b)	30	1992.45	.213236	6.97428	8.12963	18.0889	0.28
Total	53	5842.41	.454294	8.31595	25.8131	18.1443	.547988

Appendix V **Mean square values different crop characters of wheat as affected by sowing depth and population density**

Source of variation	Degrees of freedom	Mean square	
		Straw yield	Harvest index
Replication	2	3.14	20.06
Sowing depth (D)	2	7.89	2.07
Error (a)	4	1.33	30.06
Population density (P)	5	7.77	50.58
D × P	10	1.06	17.21
Error (b)	30	0.82	23.39
Total	53	1.89842	35.5489

LIST OF PICTURES

Picture 1: Field view of the experiment

Picture 2: Field view of the Treatment 2 cm depth x 100 seeds/m2

Picture 3: Field view of the Treatment 2 cm depth x 400 seeds/m2

Picture 4: Field view of the Treatment 4 cm depth x 100 seeds/m2

Picture 5: Field view of the Treatment 4 cm depth x 300 seeds/m2

Picture 6: Field view of the Treatment 6 cm depth x 300 seeds/m2

Picture 7: Field view of the Treatment 6 cm depth x 600 seeds/m2