

**EFFECT OF DIFFERENT FERTILIZER COMBINATIONS
ON YIELD PERFORMANCE OF SUNFLOWER
(HELIANTHUS ANNUUS L.)**



**A THESIS
BY**



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EXAMINATION ROLL NO. MS-050803**

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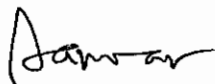
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Dedicated to
Starveling farmers of Bangladesh

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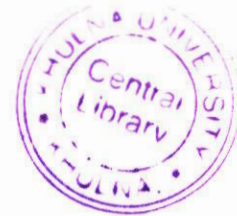
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March 2008

The Author



ABSTRACT

A field experiment was conducted at the Experimental Field of Agrotechnology Discipline, Khulna University, Khulna during the period from December 2006 to March 2007 to examine the impact of applied nutrients on agronomic characters of sunflower. The study was conducted in a Factorial Randomized Complete Block Design (RCBD) with three replications. Two varieties (Factor A) namely Local Variety and Kirani and six fertilizer treatments (Factor B) $T_1 = N\ 0\ kg\ ha^{-1}, P\ 0\ kg\ ha^{-1}, K\ 0\ kg\ ha^{-1}, Zn\ 0\ kg\ ha^{-1}, S\ 0\ kg\ ha^{-1}$; $T_2 = N\ 140\ kg\ ha^{-1}, P\ 140\ kg\ ha^{-1}, K\ 140\ kg\ ha^{-1}, Zn\ 40\ kg\ ha^{-1}, S\ 6\ kg\ ha^{-1}$; $T_3 = N\ 120\ kg\ ha^{-1}, P\ 120\ kg\ ha^{-1}, K\ 120\ kg\ ha^{-1}, Zn\ 35\ kg\ ha^{-1}, S\ 5\ kg\ ha^{-1}$; $T_4 = N\ 100\ kg\ ha^{-1}, P\ 100\ kg\ ha^{-1}, K\ 100\ kg\ ha^{-1}, Zn\ 30\ kg\ ha^{-1}, S\ 4\ kg\ ha^{-1}$; $T_5 = N\ 80\ kg\ ha^{-1}, P\ 80\ kg\ ha^{-1}, K\ 80\ kg\ ha^{-1}, Zn\ 25\ kg\ ha^{-1}, S\ 3\ kg\ ha^{-1}$; $T_6 = N\ 80\ kg\ ha^{-1}, P\ 80\ kg\ ha^{-1}, K\ 40\ kg\ ha^{-1}, Zn\ 20\ kg\ ha^{-1}, S\ 2\ kg\ ha^{-1}$ were used in the experiment. Data on yield and different yield contributing characters were collected. Fertilizer treatments showed significant effect on yield and yield contributing characters of sunflower. However, varietal effect was nonsignificant in all cases except plant height and effect of interaction of fertilizer and variety was significant in case of head diameter, number of filled seeds head⁻¹ and seed yield but nonsignificant effect was observed in all other cases. Except plant height, stover yield and harvest index; all other yield parameters were found maximum in the treatment T_3 . As expected, the control treatment (where no fertilizer was applied) possessed the worst performance for all the characters studied except plant height and harvest index. Numerically Kirani (V_2) showed higher performance than local variety (V_1) in most cases. Variable effects of variety x fertilizer combinations were observed in the study. Seed yield of sunflower was well correlated to head diameter, stover yield and harvest index.

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CHAPTER I

INTRODUCTION

Sunflower (*Helianthus annuus L.*) is an important oilseed crop in many countries of the world. In Bangladesh sunflower is not grown commercially, although there is a great scope of growing this crop. It has been cultivated in the country as an ornamental plant since 1975. Now a days it is being cultivated in different parts of the country namely Rajshahi, Jessore, Kushtia, Natore, Pabna, Dinajpur, Gazipur and Tangail districts (BARI, 2000a).

Sunflower seed contains 40-45% oil and about 55% linoleic acid (BARI, 2000b). Among the vegetable oils, sunflower oil is considered as most suitable for human consumption because of high level of linoleic acid and absence of linolenic acid. The seed has no pungency as it does not contain the harmful erocic acid, the presence of which in mustard is responsible for health hazard. The proportion of linoleic acid in sunflower is higher than that of mustard oil. For this reason sunflower oil is beneficial to health (Halder, 1995).

Besides cooking, sunflower oil is also a major ingredient in some margarine and shortening products. It is used to some extent in certain paints, varnishes and plastics because of good semi-drying proprties. This is also used in the manufacture of soaps and detergents. Sunflower meal is used as an animal food protein concentrate. Sunflower hulls are used as roughages in animal food and as fuel. Other uses are making insulatin board and litre for livestock (Giri, 1992).

Sunflower is a short duration and photo-insensitive crop and therefore, it can be grown round the year provided there is no water stagnation. Besides, it is tolerant to drought and salinity. Thus, this crop can easily be cultivated in the southern parts of the country where a vast saline area remains fallow round the year (Kundu, 1996). Scientists also consider that sunflower is an ideal crop to be used in the multiple cropping systems (Ram, 1986). As the domestic oil production at present can cover not more than only 30% of the national requirement incorporation of sunflower in the cropping patterns of Bangladesh can be considered as a most favorable attempt to reduce the import of oil and oilseeds to some extent (BBS, 1996).

Sunflower is an exhaustive crop and therefore, shows a good response to fertilizer applications (Singh *et al.*, 1973; Girase *et al.*, 1975). It is supposed to deplete the soil fertility besides producing allelochemicals (Hunsigi and Krishna, 1998). Further, one of the agronomic practices to boost yield of sunflower is to correct fertilizer application in terms of both quality and quantity. It has been reported that fertilizers in addition to their general effects on crop growth play a positive role to correct the physiological disorders in sunflower *viz.* early browning of leaves, bronzing of lower leaves and top breaking at heading (Meah, 1996). Sometimes, these disorders may seriously affect sunflower production particularly top breaking at heading that may result in a total crop failure. Therefore, it seems that the protection of a sunflower crop through an adequate and balanced supply of plant nutrients is a prerequisite to maximize the yield. Reports elsewhere evidenced that a sunflower crop, in addition to the commonly used NPK fertilizers, requires some other fertilizers including sulphur, magnesium and few micro-nutrients for its higher yield. Each of boron, sulphur, zinc and magnesium has a great role in increasing seed yield and oil content in sunflower seeds (Gangadhara *et al.*, 1990). Boron deficiency in this crop is

reported to cause deformation of heads both prior to and during flowering, and also weaken the stem behind the head leading to fracture (Anwar *et al.*, 1995).

The aims of fertilizer dressing in sunflower are, therefore, to increase the crop growth and development, and at the same time, to satisfy and improve the overall nutritional aspects of the crop. This research was conducted in order to address the following objectives:

- to study the growth and yield performance of sunflower varieties at different fertilizer combinations.

CHAPTER II

REVIEW OF LITERATURE

Sunflower is a recently introduced oilseed crop in Bangladesh. It may play an important role to mitigate edible oil demand of her people. Farmers are interested in cultivating sunflower as it is a high oil yielding crop compared to the other oilseed crops grown in the country. This crop has got considerable potentiality under Bangladesh condition as it can be grown on a variety of soils. The crop can also be cultivated round the year because of its photo-insensitive nature. Literatures pertinent to this study, especially under Bangladesh condition, are not enough. However, the author tried to present available review related to the present problem.



EFFECT OF DIFFERENT FERTILIZER ELEMENTS ON SUNFLOWER GROWTH AND YIELD

Effect of NPK fertilizers

Singh and colleagues (1973) found that sunflower was an exhaustive crop and therefore, showed a good response to fertilizer applications and high doses of nitrogen resulted in excessive vegetative growth but reduced oil content in seeds.

Zubriski and Zimmerman (1974) reported that fertilizers applied at tile rate of 56 kg N and 112 kg P_2O_5 ha⁻¹, increased seed yield by 370 and 930 kg ha⁻¹, respectively. Rajan (1974), however, reported that a combination of 40 kg N and 60 k g P ha⁻¹ was the most economical fertilizer dose for this crop.

Stamboliev and Boresov (1975) reported that sunflower was given either no fertilizer or 90-180 kg N, 80-180 kg P₂O₅ and 80-120 kg K₂O ha⁻¹ in three combinations. Among the fertilizing elements nitrogen was the most effective in increasing seed yield, but it reduced seed oil content. They further stated that addition of PK to N increased N utilization by plants, which in turn, increased seed yield and seed oil content. However, P alone was the most effective fertilizer in increasing seed oil content. According to these researchers a combination of 120-120-120 kg N-P₂O₅-K₂O ha⁻¹ was the required fertilizer rate.

Girase and coworkers (1975) conducted an experiment with 50 or 75 kg N ha⁻¹ as urea and 0, 25, 50 or 75 kg P ha⁻¹ as single superphosphate. Results showed that yield contributing characters positively responded up to 25 kg P ha⁻¹ level. Besides, application of N did not influence seed yield or oil content. Similar results have been reported by Singh and Kushal (1975).

Quadri (1975) found that seed yield increased significantly with increased rates of N application. The effect of N on seed yield was mainly accounted for larger size of head, higher number of filled seeds head⁻¹ and 1000-seed weight, and reduction in the number of unfilled seeds where nitrogen was applied as compared to control. However, Vijay and coresearchers (1975) reported that application of NPK did not significantly increase the seed yield of sunflower.

Grinev (1976) reported that the average seed yield without NPK ranged from 2.43 to 2.80 t ha⁻¹. The yield ranged from 2.96 to 3.54 t ha⁻¹ with the application of 120 kg N, 120 kg P₂O₅ and 90 kg K₂O ha⁻¹.

Singh and associates (1977) found that seed yield increased with increased N application up to 60 kg ha⁻¹. Bhosle and coworkers (1977) reported significantly higher seed yield in sunflower as achieved at higher levels of N application over control.

Lichev and colleagues (1978) in their experiment used 0, 60, 120, 180 or 240 kg N and 60, 80, 160 or 240 kg P₂O₅ ha⁻¹ in various combinations with or without 120 or 240 kg K₂O. The crop grown without fertilizers gave a seed yield of 1.58 t ha⁻¹ on grey forest and podzolic Cinnanionic forest soils and 3.16 t ha⁻¹ on a leached Chernozem soil.

Salam and coworkers (1978) reported that the increasing N rates increased the head diameter and number of seeds head⁻¹ in different varieties of sunflower.

Gowda and Gajanan (1979) found that increasing rates of N from 0-90 kg ha⁻¹ increased seed yields of sunflower. Gowda and coworkers (1979) also observed that 60 kg N ha⁻¹ gave an economic yield of 1.63 t ha⁻¹ and that a further increase of nitrogen was not economically viable.

Zubriski and colleagues (1979) reported that N fertilizer increased seed yields significantly by 70%. The average seed yields were increased by 0.07 and 0.10 t ha⁻¹ for 7.34 and 14.68 kg N ha⁻¹, respectively applied either in the form of ammonium nitrate or urea but oil percentage decreased.

Singh and associates (1988) assessed that seed yield increased with increased N application. Daulay and Singh (1980) observed that seed yield of sunflower was significantly influenced by application of N. The authors also reported significant differences in the seed yield with application of P.

✧ Blamey and Chapman (1981) observed that protein and oil content were influenced due to water supply and nitrogen application. Tripathi and Sawhney (1989), and Singh and Singh (1980) also reported similar results.

Tripathi and Kalra (1981) reported that sunflower grown in the summer season gave the highest seed yield with 40 kg N ha⁻¹ in 1974 and 120 kg N ha⁻¹ 1975. Phosphorus and potash each at 60 kg ha⁻¹, also increased seed yields.

✧ Chaudhary and Paturde (1981) observed that low rate of N (30 kg ha⁻¹) gave significantly higher seed yield over the control. They further reported that P increased oil content but not the seed yield of sunflower.

✧ Barberis and coworkers (1982) reported that application of N did not increase seed yields of sunflower unless P was applied. A mean increase in seed yield of 191 kg ha⁻¹ was obtained with 40 kg P₂O₅ ha⁻¹. The efficiency of P utilization decreased with increasing rates of applied P and with increasing levels of available soil P. According to them, fertilizers had no effect on seed oil content.

✧ Nazir and colleagues (1984) reported that sunflower *cv.* Cargil was given different combinations of 0, 50 or 75 kg N, 0 or 50 kg P₂O₅ and 0 or 50 kg K₂O kg ha⁻¹ at sowing. Results showed that NPK had no significant effect on seed number capitulum⁻¹. Plant height was highest (202cm) with 75 kg N ha⁻¹. The use of NPK increased seed number capitulum⁻¹ and seed yield plant⁻¹, but had no significant effect on 1000-seed weight or seed oil content compared to the control. However, seed yield was highest (2.78 t ha⁻¹) with 75 kg N ha⁻¹, which was similar to that obtained from 50 kg K₂O ha⁻¹, and most of the NPK treatments decreased oil contents compared to the control.

Satyanarayana and coworkers (1985) reported that while fertilizer at the rate of 30, 60 and 90 kg N ha⁻¹ was applied in 2-3 splits, 60 kg N ha⁻¹ applied in 3 splits gave the highest seed yield. The rates of N and application methods had no significant effect on oil content.

Patil and associates (1989) assessed nitrogen, phosphorus and potassium uptake in three varieties (EC 58414, Modern and Surya) at five sowing dates in 1984. The highest nutrient uptake was obtained by varieties sown on 19 April but oil content was highest in those sown on 25 February. Surya, however, gave the best oil yield (1.0 t ha⁻¹) with the maximum uptake of all the three nutrients.

Sharma and Gaur (1988) reported that application of 30, 60 and 90 kg N ha⁻¹ gave 1.80, 2.08 and 2.28 t ha⁻¹ seed yields of sunflower, respectively. Besides, these treatments had seed oil content of 42.99, 41.95 and 40.49% and seed protein content of 17.17, 18.11 and 18.51%, respectively. The increases in oil content and seed protein was due to progressive increase in the rate of fertilizer-N were similar to that reported by Simanskii (1961).

Shelke and colleagues (1988) observed that sunflower gave seed yields ranging 0.83-1.08, 1.14 -1.20 and 1.36 - 1.37 t ha⁻¹ with 0, 50 and 100 kg N ha⁻¹ respectively. In 1984-85, yield increased from 1.00 to 1.19 t with 40 kg P₂O₅ ha⁻¹, but further increase in P₂O₅ up to 80 kg did not show any positive response. They did not find any significant effect of P rates on seed yields. The 1000-seed weight increased with increasing N rates but was not affected by P or K rates.

Shin (1988) conducted trials of sunflower during 1983-84, with eight combinations of 0-120 kg N, 0-80 kg P_2O_5 and 0-80 kg K_2O ha⁻¹ and obtained maximum seed yield with the dose of 0-120 kg N, 80 kg P_2O_5 and 80 kg K_2O ha⁻¹. The yield declined by reducing the K rate to 40 kg ha⁻¹ but that effect was not enough to be significant. He suggested that NPK rates did not affect seed oil content. The author further indicated that seed yield, capitulum diameter and plant height increased with increased N rate and that seed yield was positively correlated with capitulum diameter.

Khokani and associates (1993) found that nitrogen fertilization increased seed yield, stalk yield and oil content, and uptake of N, P and K up to 90 kg ha⁻¹, but significant differences were observed only up to 60 kg ha⁻¹. They further reported that phosphorus had no effect on yield as well as oil content. Massey (1971) obtained similar results.

Jagatap and Sabale (1994) carried out an experiment at Pune, Maharashtra. Sunflower varieties EC- 68414 and Modem were given 0-100 kg N and 0-50 kg P_2O_5 ha⁻¹. Seed yield was higher in EC-68414 than in Modem and it increased significantly with fertilizer applications up to 50 kg N and 25 kg P_2O_5 ha⁻¹.

Bhowmik and coworkers (1994) reported that sunflower variety Mordem grown with 0, 40 or 80 kg P_2O_5 and K_2O ha⁻¹ and obtained highest seed yield with 40 kg P_2O_5 or K_2O ha⁻¹.

Manoharan and associates (1994) conducted an experiment at Madurai, Tamil Nadu with sunflower and applied 20-80 kg N ha⁻¹. They reported that the seed yield and seed oil content increased successively up to 60 kg N ha⁻¹.



* Annadurai and Palaniappan (1994) carried out an experiment on a sandy loam soil in 1990-91 at Coimbatore, Tamil Nadu. Sunflower variety C01 was given 0-40 kg K₂O ha⁻¹ as muriate of potash and 0 or 20 kg P₂O₅ as a single super phosphate or sprayed with 1.75% KCI at 30, 45 or 60 days after sowing. Seed yield and seed oil content were higher (1.46 t ha⁻¹ and 4.43%, respectively) with 40 kg K₂O and 20 kg P₂O₅. The application of K increased N uptake but did not affect the uptake of P and K.

* Nandhagopal and coresearchers (1995) considered 90 kg N and 60 kg P₂O₅ ha⁻¹ as optimum dose of fertilizer for sunflower seed yield. They suggested that seed oil content was not influenced by fertilizer doses.

* Bindra and Kharwara (1994) carried out a field experiment with three plant populations of 83,000, 1,11,000 and 1,67,000 plants ha⁻¹ that were adjusted with spacing of 60 cm x 20 cm, 45 cm x 20 cm and 30 cm x 20 cm, respectively. They found that plant height increased with the increase in level of N from 0 to 90 kg N ha⁻¹ at all the growth stages. However, 90 kg N ha⁻¹ produced significantly taller plants than all other levels of nitrogen.

* Chaniara and colleagues (1989) reported that plant height increased significantly at 40 kg N ha⁻¹ but N above this rate up to 80 kg N ha⁻¹ did not significantly increase plant height. They also found that LAI increased from 2.65 at 40 kg N ha⁻¹ to 3.26 at 80 kg N ha⁻¹.

* Jehan-Bakht and coresearchers (1989) grew alone and in alternate single rows, double rows and triple rows in maize and sunflower and observed that the plant height of the crop both in monoculture and interculture with 0, 60, 90, 120, 150 and 180 kg N ha⁻¹ was significantly affected.

Karunakaran and Palaniappan (1989) during the rainy season in India with sunflower, *Azospirillum* was inoculated with four levels of N (0, 20, 30, 40 kg ha⁻¹), P and K each at 20 kg ha⁻¹ were applied basally. Application of 40 kg N ha⁻¹ increased the head size significantly and with the increase in N rate there was also an increase in 1000-seed yield. But, they suggested that application of increased N rates reduced the number of seeds head⁻¹.

Agarwala and colleagues (1998) observed that additional application of 60 kg N ha⁻¹ increased head diameter, the number of whorls opening day⁻¹, seed filling percentage, hundred-seed weight and seed yield in all the genotypes studied. Legha and Giri (1999) on the other hand, observed that size of the capitulum increased up to 80 kg N ha⁻¹.

Steer and coworkers (1984) observed that N rates at the end of floret initiation and at anthesis of sunflower, seed number was determined by N supply before, i.e. by the number floret production.

Saleh and associates (1984) noticed that increasing N application increased fruit number head⁻¹. Hocking and coresearchers (1987) reported that nitrogen deficiency along with sulphur deficiency reduced number of seeds head⁻¹. Legha and Giri (1999) found that N application significantly increased seeds capitulum⁻¹ up to 80 kg N ha⁻¹.

Narwal and Malik (1985) found that application of N up to 60 kg ha⁻¹ improved the percentage of seed fertility. Nur (1975) observed that increasing N rate increased 1000-seed weight (TSW) significantly.

^ Sreemannarayana and coresearchers (1998) observed that at flowering stage of sunflower 100 kg N ha⁻¹ produced highest dry matter yield (33.1 q ha⁻¹). They mentioned that nitrogen application significantly increased dry matter plant⁻¹. In another experiment Jat and Giri (2000) noticed that nitrogen fertilization at a level of 30 and 60 kg N ha⁻¹ increased biomass yield by 20.6 and 37.2%, respectively. Similar results were also noticed by Legha and Giri (1999).

> Jehan-Bakht and fellows (1989) observed that N significantly affected stem yield ha⁻¹. Stem yield of monoculture sunflower was 10, 14, 11.82, 12.92, 11.48, 9.92 and 10.55 t ha⁻¹ at 0, 60, 90, 120, 150 and 180 kg N ha⁻¹, respectively.

Kasem and EI-Mesilhy (1992) observed that seed, straw and biological yields feddan⁻¹ were increased by applying nitrogen and the increase was highest with 60 kg N feddan⁻¹ in 1987 and with 40 kg N feddan⁻¹ in 1988.

~ Kamala and colleagues (1998) suggested that an additional 50 kg N ha⁻¹ over the recommended dose of 100 kg N ha⁻¹ improved crop grain weight, yield plant⁻¹ and ha⁻¹ in KBSH-1 variety of sunflower.

^ Rao and Gangasaran (1991) grew sunflower at the combinations of two N levels (40 and 80 kg ha⁻¹) and two S levels (0 and 25 kg ha⁻¹) and found that the highest stover yield of 1.89 t ha⁻¹ was produced when 80 kg N + 35 kg S ha⁻¹ was applied and the lowest of 0.89 t ha⁻¹ in control.

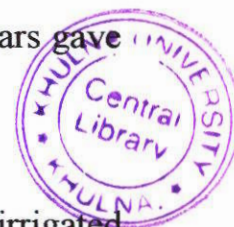
Effect of Boron

Boron plays the important role in the nutrient uptake of sunflower (Khan *et al.*, 1990). It enhances vegetative growth and absorbs other nutrients. Boron decreases seed sterility. The quality and quantity of grains are significantly influenced by the addition of boron. It also helps synthesize carbohydrates, protein and fat metabolism (Patil *et al.*, 1988).

Popov and Pyatibratov (1975) observed that application of super phosphate enriched with boron and manganese increased seed yields and oilseed content of sunflower compared to super phosphate without trace elements.

Blamey and Chapman (1981) in a study compared two varieties of sunflower PNR 40-S and SO-320 for their ability to uptake boron applied at the rate of 0-4 kg ha⁻¹. Boron application significantly increased seed size and seed oil content but decreased seed protein. With adequate boron, both cultivars gave about 2.4 t of seed yield ha⁻¹.

Hilton and Zubriski (1985) carried out an experiment at dryland and irrigated soils, with S, Zn, Fe, Cu, Mn and B, and reported that application of micronutrients did not influence seed yield or oil content. Sunflower yield from boron fertilization was not significantly different from the check, but a decreasing trend of yield was observed due to increasing rates of boron fertilization. Besides, sunflower yield from the boron treatment was significantly lower than that of both iron and sulphur treatments when all replications were combined.



Comin and associates (1987) grew sunflower variety Contisol -711 with 0, 2, 4, 8 or 12 kg B ha⁻¹ as borax applied at sowing. Soil availability of B and leaf B content increased with increasing B application. Seed yields increased with 2-4 kg B ha⁻¹ but decreased at higher B rates. Plants showed toxicity symptoms with more than 8 kg ha⁻¹ of boron application.

Kastori and Petrovie (1989) reported that sunflower hybrid NS-H-40 plants were grown for 30 days in nutrient solution containing 1, 5, 25, 100 or 500 micro mol B dm⁻³. Both the highest and lowest B concentrations decreased total N content and nitrate reduction activity, and increased the nitrate content in roots and shoots.

Sarkar and Assmal (1989) reported that boron and molybdenum among the micronutrients influenced seed yields of sunflower and the response to boron and molybdenum was significantly greater than that of Mn, Zn and Cu applied in composite forms.

Effect of Sulphur

Sulphur plays a vital role in oilseed crops as it is a constituent of sulphur bearing amino-acids (Gangwar and Parmaeswaran, 1976). Small and Sims (1977) reported that gypsum increased the emergence and yield of sunflower.

Hocking and associates (1987) showed that both S and N deficiencies reduced yields by reducing the number of seeds plant⁻¹ and by decreasing individual seed weight. Seed oil content was the same for all levels of S, but was reduced by increasing N supply.

Uziak and Szymanska (1987) used 0.6, 0.8 and 1.0 g S pot⁻¹ in addition to using recommended dose of NPK-fertilizers and reported that sunflower crop gave the highest seed yield with the dose of 0.8 g S pot⁻¹. High sulphur rate increased K: Ca, K: Mg and K: (Ca and Mg) ratios and decreased Ca: P ratio at the low NPK rate. However, Ca: P ratio increased with higher doses of NPK-fertilizers.

Gangadhara and coworkers (1990) reported that sunflower grown with 0, 2.5, 5.0 and 10.0 kg S ha⁻¹ gave seed yield of 1.62, 1.61, 1.77 and 2.03 t ha⁻¹. They suggested that S application had increased the uptake of SO₄-S, Zn, Fe, Cu and B in seeds.

Effect of Zinc

Hilton and Zubriski (1985) observed that sulphur, zinc, iron, copper, manganese and boron applications did not affect the seed yield or oil percentage of sunflower. Their field investigation further indicated that Zn, Mn and B uptake by sunflower at 12-leaf stage were significant as a result of fertilization with these elements. Increased Zn uptake from zinc fertilization was also observed in the uppermost mature leaf at anthesis.

Salama and Buzas (1987) reported that application of NPK markedly increased Fe content in plants, whereas NP decreased it. On the contrary, N and NK increased Zn and Cu content, N increased Mn and P reduced Zn. Tomar and Gangwar (1987) in their study applied 0, 20, 40 and 80 ppm P and 0.0, 2.5, 5.0 and 10.0 ppm Zn so as to investigate the availability of P and Zn and their distribution at different parts of sunflower plants. The proportion of Zn in plants derived from fertilizer increased progressively with increasing levels of zinc application.

Devaranjan and associates (1988) conducted an experiment with sunflower on a red sandy soil. In addition to NPK they applied 10 kg copper sulphate or 100 kg ferrous sulphate or 100 kg manganese sulphate or three foliar sprays with 0.5% zinc sulphate on 30, 40 and 50 days after sowing. They obtained seed yields of 2.80, 2.78, 2.75 and 2.64 t ha⁻¹, respectively compared to 1.96 t ha⁻¹ with NPK alone. Other rates of these nutrients and combination of the four nutrients at different rates did not give any remarkable variation in seed yield.

Prabhuraj and others (1993) found that seed yield of sunflower was influenced through application of sulphur and zinc with different levels of phosphorus.

Effect of Magnesium

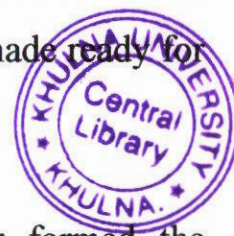
Magnesium is an important micronutrient to oilseed crops. Studies on the nutritional aspects of sunflower especially its response to the application of magnesium is very scanty in Bangladesh. The influence of magnesium on the seed as well as on the oil yield of sunflower was studied in India by Muthuvel and Rajukkannu (1983). However they did not find any significant differences in yield and oil content.

Khan and associates (1990) applied 20 kg Ca, 10 kg Mg, 2 kg B in soil and 2 kg B ha⁻¹ dusted on heads which were compared with the check in sunflower crop and obtained seed yields of 0.85, 0.80, 0.89, 1.22 and 0.65 t ha⁻¹, respectively.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna during the period from December, 2006 to March, 2007. The materials used and methodologies followed in the investigation are described below. The experimental field was situated on the eastern side of the university campus. The experimental land was opened on 14 December with a power tiller and subsequently prepared thoroughly by three ploughing with country plough followed by laddering. All weeds, stubbles and crop residues were removed and the field layout was done on 23 December. All basal doses of fertilizers were incorporated well into the soil and finally the field was made ready for sowing.



Combination of nutrients with two varieties of sunflower formed the treatment variables. The treatments were:

Factor A. Variety: 2

1. Local variety (V_1): This was a local cultivar collected from the farmer of Hogladanga, Batiaghata, Khulna. Actually this local cultivar is used by the farmer for ornamental purpose.

2. Kirani (V_2): This is a variety developed by Bangladesh Agricultural Research Institute (BARI) and was collected from Bangladesh Agricultural Development Corporation (BADC) Regional Office, Khulna.

Factor B. Fertilizer treatments: 6

$T_1 = N\ 0\ \text{kg ha}^{-1}, P\ 0\ \text{kg ha}^{-1}, K\ 0\ \text{kg ha}^{-1}, Zn\ 0\ \text{kg ha}^{-1}, S\ 0\ \text{kg ha}^{-1}$

$T_2 = N\ 140\ \text{kg ha}^{-1}, P\ 140\ \text{kg ha}^{-1}, K\ 140\ \text{kg ha}^{-1}, Zn\ 40\ \text{kg ha}^{-1}, S\ 6\ \text{kg ha}^{-1}$

$T_3 = N\ 120\ \text{kg ha}^{-1}, P\ 120\ \text{kg ha}^{-1}, K\ 120\ \text{kg ha}^{-1}, Zn\ 35\ \text{kg ha}^{-1}, S\ 5\ \text{kg ha}^{-1}$

$T_4 = N\ 100\ \text{kg ha}^{-1}, P\ 100\ \text{kg ha}^{-1}, K\ 100\ \text{kg ha}^{-1}, Zn\ 30\ \text{kg ha}^{-1}, S\ 4\ \text{kg ha}^{-1}$

$T_5 = N\ 80\ \text{kg ha}^{-1}, P\ 80\ \text{kg ha}^{-1}, K\ 80\ \text{kg ha}^{-1}, Zn\ 25\ \text{kg ha}^{-1}, S\ 3\ \text{kg ha}^{-1}$

$T_6 = N\ 40\ \text{kg ha}^{-1}, P\ 40\ \text{kg ha}^{-1}, K\ 40\ \text{kg ha}^{-1}, Zn\ 20\ \text{kg ha}^{-1}, S\ 2\ \text{kg ha}^{-1}$

The experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replications. Unit plot size was 4 m x 2.5 m. Blocks were separated by a distance of 1 m while the distance between two plots was 0.5 m.

Seeds of sunflower were sown on December 27, 2006 in 2-3 cm deep furrows maintaining a spacing of 25 cm from plant to plant and 50 cm from row to row. After placement in the furrow, seeds were covered with soil by a light pressure of hand. The experimental plots were irrigated lightly after seed sowing. Seedling emergence started after 5 days and completed within 8 days of sowing. The vacant hills were filled up by transplanting seedlings at the early stage of crop so as to maintain the desired plant population

Keeping one healthy seedling hill⁻¹ the other seedlings were carefully uprooted by hand pulling after their establishment. Weeding was done twice, once at 30 DAS and the other one at 45 DAS. Half of urea and whole amount of triple superphosphate (TSP), muriate of potash (MoP), gypsum, and zinc sulphate were applied as basal dose at the time of final land preparation and they were thoroughly incorporated with soil with the help of

a spade. The rest of Urea was side dressed in two equal splits at 30 and 45 DAS followed by 2nd and 3rd irrigation. Propping was given with bamboo sticks to five randomly selected plants from each plot on 50 DAS.

When 80% of the plant leaves as well as dorsal side of the disc turned yellowish and central disc florets dried up and shed off on touch of fingers, the crop was assessed to attain maturity. The plants from each unit plot was harvested, bundled and tagged separately. The heads were beaten with bamboo sticks to separate the seeds from heads. After separation, the seeds were winnowed to remove trashes and inert materials. Prior to storing, the seeds were sun dried for three days. The seeds were cleaned and stored in gunny bags.

Data Collection

Five plants from each plot excluding the border plants were selected randomly. Data were collected from the harvested and tagged plants on the following parameters:

1. Plant height (cm)
2. Head diameter (cm)
3. Number of filled seeds head⁻¹
4. Number of unfilled seeds head⁻¹
5. Seed yield (t ha⁻¹)
6. Stover yield (t ha⁻¹)
7. Weight of 1000-seeds (g)
8. Harvest index (%)

Statistical Analysis:

All the collected data were subjected to statistical analysis following the ANOVA technique. The means were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Regression analysis was done between yield and yield attributes.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the present study regarding the influence of applied nutrients on agronomic characters of sunflower have been presented and discussed in this chapter in different heads. All the growth, yield and yield attributes were influenced significantly by fertilizer application. However, effect of variety was significant only on plant height and effect of variety and fertilizer interaction was significant on head diameter, number of filled seeds head⁻¹ and seed yield.

Plant height

From the study it was found that the effect of the fertilizer treatment on plant height of sunflower was significant (Table 1). The plant height of sunflower varied from 98.10 cm to 175.87 cm. The highest plant height (175.87 cm) was found in T₂ treatment and the lowest (98.10 cm) in T₆ treatment and these two values differed statistically between them as well as to other fertilizer treatments. The result is in agreement with that of El-Sayed and associates (1984) and Vivek and Chakor (1992). The authors found that N had significant effect on plant height. Besides Prabhuraj and coworkers (1993) reported that the height of sunflower plant increased with S application. Significant difference in plant height was found between the two varieties. The plant height was shorter in V₁ (122.66 cm) than in V₂ (127.54 cm) (Table 2). The interaction effect of variety and fertilizer treatments on plant height of sunflower was nonsignificant. However, the highest plant height (222.97 cm) was found in the combination of V₂T₄ and that was the lowest (96.16) in the combination of V₁T₆ (Table 3).

Head diameter

Plant head diameter under different fertilizer treatments differed significantly (Table 1). The plant head diameter varied from 7.01 cm to 12.85 cm. The largest head diameter (12.85 cm) was found in T_3 treatment which was statistically similar to those observed in T_2 , T_4 and T_5 but dissimilar to those observed in T_6 and T_1 treatments. The lowest plant head diameter (7.01 cm) was recorded in T_1 treatment which was statistically similar to those observed in T_6 but dissimilar to those observed in T_2 , T_3 , T_4 and T_5 treatments. Similar results were found by Salam and coworkers (1978) who reported that the increasing N rates increased the head diameter and number of seeds head⁻¹ in different varieties of sunflower. Head diameter was greater in V_2 (11.03 cm) than in V_1 (10.46 cm) (Table 2). Interaction of variety and fertilizer treatments on plant head diameter had significant effect (Table 3). The highest head diameter (13.67 cm) was found in the combination of V_2T_2 that was statistically similar to those observed in the combination of V_1T_3 , V_1T_5 , V_2T_3 and V_2T_4 and the lowest (7.00 cm) in the combination of V_2T_1 that was statistically similar to those observed in the combination of V_1T_1 and V_1T_6 .

Plotting seed yield against head diameter of sunflower yielded a straight line suggesting that head diameter had a positive effect on seed yield (Fig.1). It also indicated that seed yield increased by 0.0031 t ha⁻¹ for each unit increase in head diameter. More than 80% in the variation of seed yield could be explained by the variation in head diameter (Fig.1).

Number of filled seeds head⁻¹

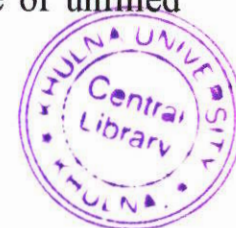
Number of filled seeds head⁻¹ differed widely among various fertilizer levels. The number of filled seeds head⁻¹ varied from 206.2 to 511.5 (Table 1). The highest number of filled seeds head⁻¹ of sunflower (511.5) was obtained in T_3

treatment that was statistically similar to those recorded in T_2 , T_4 and T_5 treatments but dissimilar to that found in T_6 and T_1 treatments. The lowest number of filled seeds head⁻¹ (206.2) was recorded in T_1 which was statistically similar to that observed in T_6 but dissimilar to those recorded in T_2 , T_3 , T_4 and T_5 treatments. The result was in agreement with those of Nazir and colleagues (1984) and Salam and coworkers (1978). The value of number of filled seeds head⁻¹ in V_1 (398.24) was higher than that of V_2 (336.72) even if they did not differ remarkably (Table 2). Significant interaction effect of fertilizer and variety on filled seeds head⁻¹ was observed (Table 3). The highest filled seeds head⁻¹ (564.13) was found in the combination of V_1T_5 that was statistically similar to those observed in the combination of V_1T_2 , V_1T_3 , V_2T_2 , V_2T_3 and V_2T_4 and the lowest (205.33) in the combination of V_2T_1 that was statistically similar to those observed in the combination of V_1T_1 , V_1T_4 , V_1T_6 and V_2T_6 .

Number of unfilled seeds head⁻¹

Number of unfilled seeds head⁻¹ was significantly influenced by the use of different fertilizer combinations. Numerically the maximum number of unfilled seeds head⁻¹ (45.13) was found in T_3 treatment which was statistically similar to those recorded in T_2 , T_4 and T_5 but dissimilar to those observed in T_1 and T_6 . The minimum number of unfilled seeds head⁻¹ (22.03) was recorded in T_1 treatment that was statistically similar to unfilled seeds obtained in T_6 treatment but dissimilar to those obtained in T_2 , T_3 , T_4 and T_5 (Table 1). The number of unfilled seeds head⁻¹ was 35.27 and 32.6 in V_2 and V_1 , respectively (Table 2). Number of unfilled seeds head⁻¹ did not differ significantly by the interaction effect of fertilizer and variety. V_2T_3 gave the highest number of unfilled seeds head⁻¹ (46.07) and V_2T_1 gave the lowest (21.27) (Table 3). Similar results were also found by Oguneremi (1983). He concluded that application of increased N rates increased the percentage of

hollow seeds in a head. Karami (1980) noticed that percentage of unfilled seeds ha^{-1} increased with the increasing N rates.



1000-seed weight

Fertilizer levels had significant effect on 1000-seed weight of sunflower. The highest 1000-seed weight (50.65 g) was found in T_3 treatment which was statistically dissimilar to other treatments. The lowest 1000-seed weight (41.88 g) was found in T_1 treatment which was statistically identical to that in T_6 treatment but dissimilar to those in T_2 , T_3 , T_4 and T_5 treatments (Table 1). This result is in agreement with that of Nur (1975) who observed that increasing N rate increased 1000-seed weight (TSW) significantly. Kamala and associates (1998) suggested that an additional application of 50 kg N ha^{-1} over the recommended dose of 100 kg N ha^{-1} improved crop grain weight in KBSH-1 sunflower. The recorded TSW in V_1 (50.65 g) is greater than V_2 (41.88 g) (Table 2). Interaction of fertilizer and variety had no effect on 1000-seed weight. However the maximum (50.67 g) and minimum (41.37 g) TSW were found in V_2T_3 and V_2T_1 , respectively (Table 3).

Regression analysis between 1000-seed weight and seed yield of sunflower revealed that seed yield is highly dependent on 1000-seed weight and over 80% of the variation in seed yield could be explained by the variation in 1000-seed weight (Fig.2).

Seed yield

Different fertilizer treatments had shown positive effect on seed yield of sunflower. The highest seed yield (2.03 t ha^{-1}) was recorded with T_3 treatment that was statistically identical to those recorded in T_2 , T_4 and T_5 treatments (Table 1). The lowest yield (0.70 t ha^{-1}) was found when no fertilizer was used and it was statistically similar to T_6 treatment but

dissimilar to others (Table 1). Kalra and Tripathi (1980) also found that seed yield increased with uptake of NPK fertilizers. The higher yield in T_3 treatment might be attributed to greater head diameter, more number of filled seeds head^{-1} and heavier seeds. Hunsigi and Krishna (1998) also reported that yield of sunflower mainly depends on number of heads ha^{-1} , number of seeds ha^{-1} and average weight of seeds. In V_2 seed yield (1.53 t ha^{-1}) was higher than that of V_1 (1.44 t ha^{-1}) (Table 2). Interaction of fertilizer and variety had significant effect on seed yield (Table 3). The maximum (2.07 t ha^{-1}) seed yield was found in the combination of V_2T_3 which was statistically similar to that recorded in the combination of V_1T_3 , V_1T_5 , V_2T_2 and V_2T_4 whereas the minimum (0.68 t ha^{-1}) seed yield was recorded in the combination of V_2T_1 which was statistically similar to that recorded in the combination of V_1T_1 , V_1T_6 and V_2T_6 but dissimilar to that recorded in other combinations.

Stover yield

Stover yield differed significantly due to different fertilizer levels. Treatments T_2 and T_1 gave the maximum (4.92 t ha^{-1}) and minimum (1.21 t ha^{-1}) stover yield respectively. The maximum yield was statistically identical to those recorded in T_3 , T_4 and T_5 treatments whereas the minimum yield was statistically identical to those recorded in T_6 treatment (Table 1). Stover yield in V_2 (3.51 t ha^{-1}) was higher than that of V_1 (3.21 t ha^{-1}). Stover yield did not vary significantly due to interaction effect of fertilizer and variety. The maximum (5.69 t ha^{-1}) and the minimum (1.13 t ha^{-1}) stover yield were found in V_2T_2 and V_2T_1 , respectively (Table 3). Rao and Gangasaram (1991) reported that $80 \text{ kg N} + 35 \text{ kg S ha}^{-1}$ produced higher stover yield than $40 \text{ kg N} + 0 \text{ kg S ha}^{-1}$. Sreemanarayana and Raju (1994) found the highest seed yield and stalk yield at the highest dose of 60 kg S ha^{-1} over the control.

Regression analysis taking stover yield as independent variable and seed yield as dependent variable showed a linear and positive relationship (Fig. 3). This result indicates that seed yield (t ha^{-1}) increased with the increment of stover yield (t ha^{-1}) in sunflower. The higher value of R^2 revealed that more than 80% of the variation in seed yield of sunflower could be explained by the variation in stover yield.

Harvest index

Result of the present study revealed that harvest index (HI) of sunflower was influenced widely by fertilizer treatments (Table 1). The maximum harvest index (36.68%) was recorded in T_1 treatment which was statistically similar to those recorded in T_3 , T_4 and T_6 treatments but dissimilar to those recorded in T_2 and T_5 treatments. The minimum harvest index (25.46%) was recorded in T_5 which was statistically similar to those recorded in T_2 , T_3 and T_4 . V_2 gave the higher harvest index value (32.16%) than V_1 (31.33 %) (Table 2). However, harvest index did not differ significantly due to interaction effect of fertilizer and variety. V_2T_1 gave the highest HI (37.43 %) and V_2T_5 gave the lowest (24.15) (Table 3). Faruk (2002) concluded that nitrogen fertilization had no effect however; sulphur fertilization had significant effect on harvest index of sunflower. He also showed that nitrogen and sulphur combinedly influenced harvest index in their combined effect.

Table 1. Effect of fertilizer on yield and yield contributing characters of sunflower

Treatment	Plant height (cm)	Head diameter (cm)	Number of filled seeds head ⁻¹	Number of unfilled seeds head ⁻¹	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest Index (%)
T ₁	102.13e	7.01b	206.20b	22.03c	41.88e	0.70b	1.21b	36.68a
T ₂	175.87a	12.70a	484.27a	38.63ab	49.48b	1.80a	4.92a	27.70bc
T ₃	140.42b	12.85a	511.50a	45.13a	50.65a	2.03a	4.10a	33.21abc
T ₄	120.95c	11.58a	444.53ab	35.46ab	47.38c	1.73a	3.49a	32.49abc
T ₅	113.12d	11.90a	476.77a	34.2abc	45.37d	1.62a	4.51a	25.46c
T ₆	98.10f	8.40b	288.13b	28.13bc	44.6d	1.04b	1.91b	34.90ab
LS	**	**	**	**	**	**	**	**
CV (%)	1.38	8.27	20.31	19.99	1.15	15.05	25.81	13.25

Figures bearing letter (s) in common did not differ significantly, whereas figures with dissimilar letter (s) differ significantly.

Table 2. Varietal differences in yield and yield contributing characters of sunflower

Variety	Plant height (cm)	Head diameter (cm)	Number of filled seeds head ⁻¹	Number of unfilled seeds head ⁻¹	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest Index (%)
V ₁	122.66b	10.46	398.24	32.60	46.72	1.44	3.21	31.33
V ₂	127.54a	11.03	336.72	35.27	46.41	1.53	3.51	32.16
F value	71.02	3.73	0.07	1.36	4.89	1.60	1.05	0.36
LS	**	NS	NS	NS	NS	NS	NS	NS
(CV%)	1.38	8.27	20.31	19.99	1.15	15.05	25.81	13.25

V₁= Local variety

V₂= Kirani

Table 3. Effect of interaction of Variety X Fertilizer on yield and yield contributing characters of sunflower

Treatment combination	Plant height (cm)	Head diameter (cm)	Number of filled seeds head ⁻¹	Number of unfilled seeds head ⁻¹	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Harvest index (%)
V ₁ T ₁	99.97	7.03e	207.07e	22.80	42.40	0.72f	1.29	35.93
V ₁ T ₂	173.03	11.73bc	464.73abc	33.40	49.43	1.60bcd	4.14	28.58
V ₁ T ₃	137.90	12.33abc	510.00ab	44.20	50.63	1.98ab	3.81	34.08
V ₁ T ₄	118.93	11.07c	347.67cde	31.13	47.70	1.43cde	3.26	29.18
V ₁ T ₅	109.93	12.90ab	564.13a	37.07	45.50	1.84abc	4.67	26.77
V ₁ T ₆	96.16	7.67de	295.87de	27.00	44.63	1.07ef	2.06	33.36
V ₂ T ₁	104.30	7.00de	205.33e	21.27	41.37	0.68f	1.13	37.43
V ₂ T ₂	178.70	13.67a	503.80ab	43.87	49.53	1.99ab	5.69	26.82
V ₂ T ₃	142.93	13.37ab	513.00ab	46.07	50.67	2.07a	4.38	32.34
V ₂ T ₄	222.97	12.10abc	541.40ab	39.80	47.07	2.03ab	3.72	35.80
V ₂ T ₅	116.30	10.90c	389.40bcd	31.33	45.23	1.41de	4.36	24.15
V ₂ T ₆	100.03	9.13d	280.40de	29.27	44.57	1.00f	1.75	36.43
LS	NS	*	*	NS	NS	*	NS	NS
CV (%)	1.38	8.27	20.31	19.99	1.15	15.05	25.81	13.25

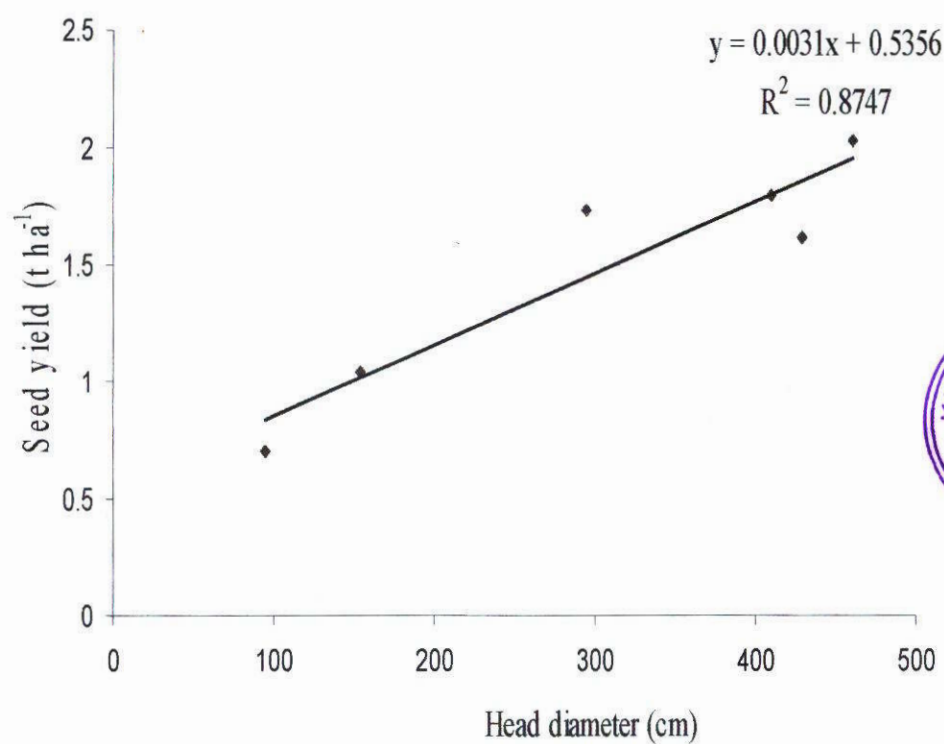


Fig. 1. Functional relationship between seed yield (t ha⁻¹) and head diameter (cm) of sunflower.

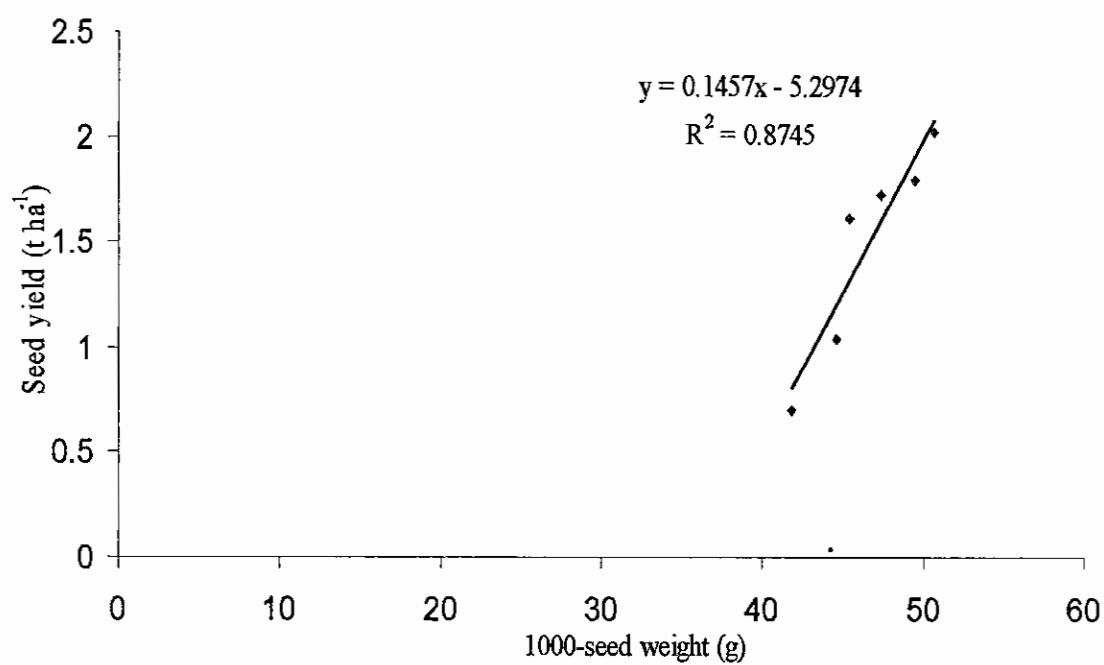


Fig. 2. Functional relationship between seed yield (t ha⁻¹) and 1000-seed weight (g) of sunflower.

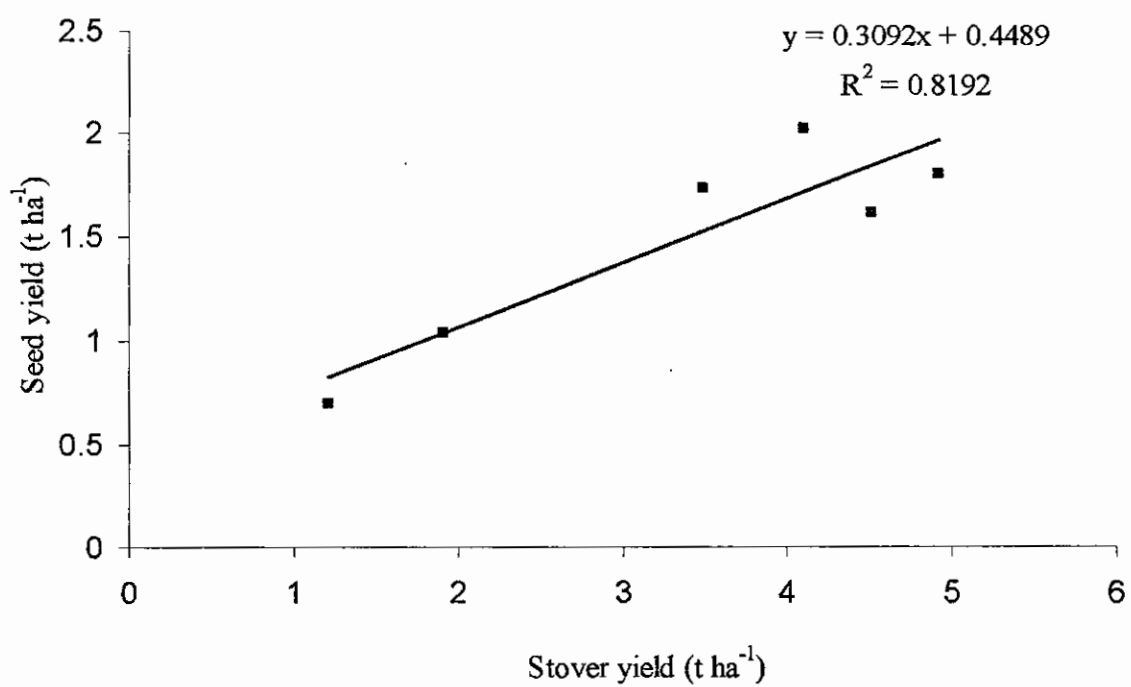


Fig. 3. Functional relationship between seed yield (t ha⁻¹) and stover yield (t ha⁻¹) of sunflower.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna during the period from December, 2006 to March, 2007 to evaluate the effect of different fertilizer materials on yield and yield attributes of sunflower. The study was conducted in a Factorial Randomized Complete Block Design (RCBD) with three replications. Two varieties (Factor A) namely Local Variety and Kirani and six fertilizer combinations (Factor B) $T_1 = N\ 0\ kg\ ha^{-1}, P\ 0\ kg\ ha^{-1}, K\ 0\ kg\ ha^{-1}, Zn\ 0\ kg\ ha^{-1}, S\ 0\ kg\ ha^{-1}$; $T_2 = N\ 140\ kg\ ha^{-1}, P\ 140\ kg\ ha^{-1}, K\ 140\ kg\ ha^{-1}, Zn\ 40\ kg\ ha^{-1}, S\ 6\ kg\ ha^{-1}$; $T_3 = N\ 120\ kg\ ha^{-1}, P\ 120\ kg\ ha^{-1}, K\ 120\ kg\ ha^{-1}, Zn\ 35\ kg\ ha^{-1}, S\ 5\ kg\ ha^{-1}$; $T_4 = N\ 100\ kg\ ha^{-1}, P\ 100\ kg\ ha^{-1}, K\ 100\ kg\ ha^{-1}, Zn\ 30\ kg\ ha^{-1}, S\ 4\ kg\ ha^{-1}$; $T_5 = N\ 80\ kg\ ha^{-1}, P\ 80\ kg\ ha^{-1}, K\ 80\ kg\ ha^{-1}, Zn\ 25\ kg\ ha^{-1}, S\ 3\ kg\ ha^{-1}$; $T_6 = N\ 40\ kg\ ha^{-1}, P\ 40\ kg\ ha^{-1}, K\ 40\ kg\ ha^{-1}, Zn\ 20\ kg\ ha^{-1}, S\ 2\ kg\ ha^{-1}$ were used as treatment variables in the experiment. Five plants from each plot excluding the border plants were selected randomly at maturity. Data were collected from the harvested and tagged plants on different parameters namely, plant height (cm), head diameter (cm), number of filled seeds head⁻¹, number of unfilled seeds head⁻¹, weight of 1000-seeds (g), seed yield (t ha⁻¹), stover yield (t ha⁻¹) and harvest index (%). Collected data were statistically analyzed following the ANOVA technique. The means were compared by Duncan's Multiple Range Test (DMRT). Functional relationships were established between yield and yield parameter following regression analysis.

From the study it was found that the effect of different fertilizer treatments on yield and yield contributing characters of sunflower was significant. On

the other hand, varietal effect was nonsignificant in all cases except plant height and effect of interaction of fertilizer and variety was significant in case of head diameter, number of filled seeds head⁻¹ and seed yield but nonsignificant effect was observed in all other cases. The highest plant height (175.87 cm) was found in T₂ treatment and the lowest (98.10 cm) in T₆ treatment. The plant height was lower in V₁ (122.66 cm) than in V₂ (127.54 cm). The highest plant height of sunflower (222.97 cm) was found in the combination of V₂T₄ and the lowest (96.16) in the combination of V₁T₆. The highest plant head diameter (12.85 cm) was found in T₃ treatment and the lowest plant head diameter (7.01cm) was found in T₁ treatment. Head diameter was greater in V₂ (11.03 cm) than in V₁ (10.46 cm). The highest head diameter (13.67 cm) was found in the combination of V₂T₂ and the lowest (7.00 cm) in the combination of V₂T₁. The highest (511.50) and lowest number of filled seeds head⁻¹ (206.20) was recorded in T₃ and T₁ treatments, respectively. The number of filled seeds head⁻¹ was 398.24 in V₁ and 336.72 in V₂. The highest (564.13) and lowest (205.33) number of filled seeds head⁻¹ were found in V₁T₅ and V₂T₁ combinations, respectively. Numerically the maximum number of unfilled seeds head⁻¹ (45.13) was observed in T₃ treatment whereas minimum (22.03) was recorded in T₁ treatment. The number of unfilled seeds head⁻¹ was 35.27 in V₂ and 32.60 in V₁. V₂T₃ gave the highest number of unfilled seeds head⁻¹ (46.07) and V₂T₁ gave the lowest (21.27). The maximum 1000-seed weight (50.65 g) was found in T₃ treatment while the lowest value (41.88g) was found in T₁ treatment. The recorded TSW in V₁ (46.72 g) is greater than V₂ (46.41 g). In the interaction of variety and fertilizer maximum (50.67 g) and minimum (41.37 g) TSW were found in V₂T₃ and V₂T₁, respectively. The highest seed yield (2.03 t ha⁻¹) was produced by T₃ treatment and the lowest yield (0.70 t ha⁻¹) was found when no fertilizer was used. In V₂ seed yield (1.53 t ha⁻¹) was higher than that of V₁. In the combined effect of variety and fertilizer

maximum (2.07 t ha^{-1}) and minimum (0.68 t ha^{-1}) seed yield were found in the combination of V_2T_3 and V_2T_1 , respectively. Treatments T_2 and T_1 gave the maximum (4.92 t ha^{-1}) and minimum (1.21 t ha^{-1}) stover yield respectively. Stover yield in V_2 (3.51 t ha^{-1}) was greater than that of V_1 (3.21 t ha^{-1}). The maximum (5.69 t ha^{-1}) and the minimum (1.13 t ha^{-1}) stover yield were found in the combination of V_2T_2 and V_2T_1 , respectively. The maximum harvest index (36.68%) was recorded in T_1 treatment and minimum value (25.46%) was recorded in T_5 treatment. V_2 gave the higher harvest index value (32.16 %) than V_1 (31.33 %). V_2T_1 gave the highest HI (37.43 %) and V_2T_5 gave the lowest HI (24.15). The results of the present study demonstrated that all the growth, yield and yield attributes were influenced significantly by fertilizer application. However, varieties as well as variety x fertilizer interaction did not show significant influence on most of the parameters studied. In fact, the present research work needs to be repeated in the forthcoming years in different agroecological zones of the country to confirm its fitness and for its generalization.

CHAPTER VI

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