EFFECT OF SOWING DATE AND POTASSIUM ON THE GROWTH AND YIELD OF SUNFLOWER IN KHARIF-I SEASON

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CERTIFICATE

*This is to certify that thesis entitled, "***EFFECT OF SOWING DATE AND POTASSIUM ON THE GROWTH AND YIELD OF SUNFLOWER IN KHARIF-I SEASON***" submitted to the Faculty of Agriculture, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.) in AGRONOMY****, embodies the result of a piece of bona-fide research work carried out by* ***SONIA AKTER SHAYLA****, Registration no.* **18-09168***under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
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DEDICATED
TO MY
BELOVED PARENTS
AND SUPERVISOR

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The Author

EFFECT OF SOWING DATE AND POTASSIUM ON THE GROWTH AND YIELD OF SUNFLOWER IN KHARIF-I SEASON

ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 (Tejgaon series under AEZ No.28) during Kharif-I (March – September), 2019 to study the growth and yield performance of BARI Surjomukhi 2 in response to sowing date, potassium and their combination. The experiment consisted of two factors: Factor A: Four sowing date viz, S_1: 21 March, S_2:21 April, S_3: 22 May, S_4: 22 June and Factor B: three levels of potassium; K_1: recommended potassium (84 kg K ha^{-1}), K_2: 125% recommended potassium (105 kg K ha^{-1}), K_3: 150% recommended potassium (126 kg K ha^{-1}). The experiment was laid out in split - plot design with three replications. Sowing date was considered to main-plot and potassium level as sub-plot. Data on different growth, yield and yield parameters were taken. Result revealed that S_1 (21 March) showed highest plant height (141.60 cm) at 80 DAS, head diameter (13.90 cm.) at harvest, no. of seed $plant^{-1}$ (693.6), seed yield $plant^{-1}$ (40.03 g), weight of 1000-seed (45.17 g), seed yield (2.98 t ha^{-1}), harvest index (44.51%). The lowest head diameter at harvest(12.83cm), no. of seeds $plant^{-1}$(514.33), seed yield (2.14 t ha^{-1})was obtained from 22 May (S_3).The shorten maturity days (73.78 days) found from 21 March (S_1). But in case of potassium level highest plant height (131.43cm) at 80 DAS, no. of seeds $plant^{-1}$ (613.83), seed yield $plant^{-1}$ (36.57g), weight of 1000-seed (43.00g), seed yield (2.63 t ha^{-1}) was obtained from 105kg K ha^{-1} (K_2),whereas the lowest no. of seeds $plant^{-1}$(514.33),seed yield $plant^{-1}$(30.31g), seed yield (2.45 t ha^{-1})was found from 126 kg Kha^{-1} (K_3). The maximum plant height (142.67cm), head diameter (14.90cm.), no. of seeds $plant^{-1}$ (717.67), seed yield $plant^{-1}$ (43.25g), weight of 1000-seed (46.33g) and seed yield (3.19 t ha^{-1}) were obtained with the combined effect of 21 March/105 kg K ha^{-1}(S_1K_2)while the minimum no. of seeds $plant^{-1}$ (512) and seed yield (2.08 t ha^{-1}) found by sowing on22 May applying 126 kg K ha^{-1}(S_3K_3).

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LIST OF ABBREVIATION

BARI	Bangladesh Agricultural Research Institute
et al.	And others
g	Gram
mg	milligram
LSD	Least Significant Differences
CV	Coefficient of Variation
MoP	Murate of Potash
TSP	Triple Super Phosphate
m	Meter
cm	Centimeter
ha	Hectare
m^2	Square meter
t	Ton
%	Percent
DAS	Days after sowing
DAE	Days after emergence

CHAPTER I

INTRODUCTION

Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. *Helianthus* genus contains 65 different species (Andrew *et al*., 2013). The name Helianthus, being derived from helios (the sun) and anthos (a flower), has the same meaning as the English name Sunflower, which has been given these flowers from a supposition that they follow the sun by day, always turning towards its direct rays. The sunflower that most people refer to is *H. annuus*, an annual sunflower. In general, it is an annual plant which possesses a large inflorescence (flowering head), and its name is derived from the flower's shape and image, which is often used to depict the sun. The plant has a rough, hairy stem, broad, coarsely toothed, rough leaves and circular heads of flowers (Khaleghizadeh, 2011). The heads consist of many individual flowers, which mature into seeds on a receptacle base (Seghatoleslami *et al*., 2012).

Sunflower is the world‘s fourth largest oil-seed crop and its seeds are used as food and its dried stalk as fuel. It is already been used as ornamental plant and was used in ancient ceremonies (Harter *et al*., 2004; Muller *et al*., 2011). Additionally, medical uses for pulmonary afflictions have been reported. In addition, parts of this plant are used in making dyes for the textile industry, body painting, and other decorations. Sunflower oil is used in salad dressings, for cooking and in the manufacturing of margarine and shortening (Kunduraci *et al*., 2010).

Sunflower is used in industry for making paints and cosmetics. In some countries, the seed cake that is left after the oil extraction is used as livestock feed. The dried stems have also been used for fuel. The stems contain phosphorous and potassium, which can be composted and returned to soil as fertilizer. Sunflower meal is a potential source of protein for human consumption due to its high nutritional value and lack of anti-nutritional factors (Fozia *et al*., 2008). Sunflower was a common crop among American Indian tribes throughout North America. Evidence suggests that the plant was cultivated by natives in present day Arizona and New Mexico about 3000 B.C.

Sunflower occupies the fourth position among vegetable oilseeds after soybean, oil palm and canola in the world. The major goal of growing sunflower is for its seed (achene) that contains oil (36-52%) and protein (28–32%) as reported by Rosa *et al*. (2009). The value of imported edible oils was Tk. 1, 38,141 million in 2014, (BB, 2014). Sunflower seeds are edible. It is good source of protein, vitamin, calcium, nitrogen and iron. Its seed contain 40-45% non-volatile oils and about 55% linoleic acid. Approximately it contains protein 20.8%, carbohydrate 18.4%, lipid 54.8% and ash 3.9% (Gopalan, 1982).

Sunflower is one of the most important oilseed plants that has originated from tropical and subtropical regions with wide adaptability and high drought tolerance. High water-holding soils are more suitable for this crop, but it can easily adapted to different soil conditions. In recent years, sunflower seed production has decreased, compared to the four major oilseeds (soybean, rapeseed, cottonseed, and groundnut). This is because sunflower continues to be allocated to marginal environments and soils with low fertility where drought and high temperatures may continually impair the yield per unit area. Conventionally, sunflower is sown around mid-March; grain filling and oil accumulation are reached in June and July, when high evaporative demand and rare rainfall events take place. Although the sunflower crop may rely on stored soil moisture, it remains subject to water deficits and rain (Alba, *et al.,* 2010).

The sunflower is grown in the southern part of our country in a very limited scale. Though its production is decreased due to increasing the rice area. The productivity of sunflower, in terms of growth, yield and yield components, varies widely depending on various environmental factors such as temperature (Kaleem *et al*., 2011), rainfall distribution (Lawal *et al.,* 2011; Olowe *et al*., 2013), some agronomic practices, like sowing date (Lawal *et al*., 2011; Anjum *et al*., 2012), nitrogen nutrition and sowing of improved varieties and hybrids (Ali *et al*., 2012). As sunflower is frequently planted after the optimal planting period at different conditions and regions, a new breeding formulation is needed to improve yield under these conditions. Additionally, sowing dates have greatly influenced vegetative and generative growth periods of crops (Ahmed *et al*., 2015). Sowing date has a significant influence on vegetative traits, together with seed yield and its component (Allam *et al*., 2003). The late planting is effective in delaying of emergence, flowering, and maturity in cultivars of sunflower. However, in some studies that were conducted at different ecology and climatic conditions, the sowing date is delayed, growth, seed yield, and quality (oil content) generally tended to decrease (Baghdadi *et al*., 2014; Ahmed *at al*., 2015). Oil content for sunflower is determined during the seed filling period, which is from the end of flowering to the physiological maturity (Aguirrezabal *et al.*, 2003). It is expressed that the yield and agronomic characteristics of the sunflower were notably higher in the early sown crops whereas the late sown crops showed lower yield and growth (Ali *et al.*, 2004). There are evidence that the sowing time has significant effect on both seed yield and oil contents of sunflower under varying climatic conditions (Johnson and Jellum, 1972). When emergence rate for each sowing date was calculated using a common base temperature they were found to be well correlated with rate of change of day length. Date of sowing determines time of flowering and it has great influence on dry matter accumulation, seed set and seed yield (Sofield *et al*., 1977). In addition, the seed yield, head diameter, the ratio of dehulled/hulled seed weight, 1000- seed weight, oil content of seed is positively affected by early sowing of sunflower (Abdou *et al*., 2011; Ahmed *et al*., 2015).

Results from previous studies also indicated that the seed yield can be reduced by delaying the sowing date (Baghdadi *et al*., 2014). Sowing date can show differences even if the cultivars are grown in the same ecological region. Since sunflower cultivars have their own distinctive characteristics and yield potential (Nasim *et al*., 2012) and therefore have significant differences in terms of yield and quality characteristics. To increase yield and its stability, it is necessary to take into consideration to determine the optimum sowing date for achieving higher yield of sunflower.

Amongst other factors, sowing date and potassium application may interact decisively with water supply. The major function of K in plants is in water relations. Potassium helps to maintain a favorable water status in plants in several different ways. Potassium cations dissolved in cell sap perform major K^+ also maintain the water relations in plants through their crucial role in regulating water loss by transpiration from pores in the leaves. Therefore, K deficient plants often have higher transpiration rates and display wilting. In kharif-I season, sunflower may face water logging due to heavy rainfall. K supplementation under water logging not only increased plant growth, photosynthetic pigments and photosynthetic capacity, but also improved plant nutrient uptake as a result of higher K^{+}, $Ca^{2+,}$ N, Mn^{+} and Fe^{2+} accumulation.

Therefore, a research was undertaken to evaluate the effect of sowing date and K on growth and yield of sunflower in Kharif-I season with the following objectives-

1. To study the variations in growth and yield of sunflower due to sowing date.

2. To study the variations in growth and yield of sunflower due to potassium level.

3. To evaluate the combined effect of sowing date and potassium on alleviating variations in growth and yield of sunflower.

CHAPTER II

REVIEW OF LITERATURE

Sunflower is most important oil crop in Bangladesh. It can contribute to extend our national economy. But the research work on this crop in agronomic aspect are not adequate. Only some limited studies have so far been done in respect of agronomic management practices of this crop.

2.1 Effect of sowing date

Demir (2019) set an experiment with five sowing dates at 10 days intervals on 10 April, 20 April, 1 May, 10 May and 20 May and 6 hybrid sunflower cultivars (LG-5580, SanayMr, SanbroMr, Sirena, Tarsan and Transol). The study was taken place in both rainy (2012) and dry (2013) warm conditions due to different weather in Turkey. In this way, the effects of both sowing dates and extreme climatic conditions were tested. Yield and yield components of sunflower were higher in 2012 than 2013, except dehulled/ hulled seed weight and oil content. When sowing date was delayed, seed and oil yields declined. The maximum plant height (151.18 cm), 1000-seed weight (51.72g), crude oil content (46.18%), seed yield (2.55 t ha^{-1}) and oil yield (1.18 t ha^{-1}) were obtained on the second sowing date (20 April) while the highest ratio of dehulled/hulled seed weight (70.04%) and head diameter (20.49 cm) were from sowing date 10 April in 2012. However, early April sowing resulted in higher yield and agronomic characteristics than delayed sowing due to a decrease in rainfall during the growing period. Sowing date of 20 April provided significant improvements in yield and yield parameters due to the longer growing season with suitable soil moisture, allowing sufficient time for vegetative growth and head and achenes filling.

Hilwa *et al.* (2019) was done a study to quantify the influence of sowing date on growth and yield components of hybrid sunflower (Hysun33) cultivar in semi-arid zone in Sudan. The results of this study revealed that crop sown in May and July showed significant increase in plant height, LAI, head diameter, dry weight, filled seed number/head, weight of 100-seed, yield, and yield components, compared to crop sown in March. However, crop sown in the second season showed an increase in growth and yield components compared to the crop of the first season.

Hakeem *et al*. (2017) done an experiment during 2016, at the research area near Faculty of Agriculture, Lasbela University of Agriculture, Water and Marine Science, Uthal, Balochistan. Experimental treatments were comprising three varieties of sesame, SV1 (TS-5), SV2 (TH-6) and SV3 (4002), and cultivated under different three sowing dates, at 15 days interval: S_1 = 1st sowing (15 March 2016), S_2 = 2nd sowing (1 April 2016) and S_3 =3rd sowing (15 April 2016). Highest yield and yields contributing parameters was observed in S_3 = 3rd sowing (15 April 2016) and sesame genotype SV1 (TS-5), followed by SV2 (TH-6), while minimum yield was noted in S_3 = 3rd sowing (15 April 2016) and SV3 (4002) sesame genotypes. Sowing date of sesame at 15 April 2016 was more productive, as compared to the other sowing interval.

Ozturk *et al.* (2017) investigated the effects of sowing date and nitrogen fertilizer forms on the yield and agronomic characteristics of two cultivars of oil sunflower (early, Sirena and late, Teknosol) in Erzurum, Eastern Anatolia of Turkey, in 2013 and 2015. Three sowing dates were tested at about 10 day intervals from late-April to early and mid-May (22 April, 2 May and 12 May 2013; and 28 April, 8 May and 18 May 2015). Three nitrogen fertilizer forms ammonium sulfate, ammonium nitrate, and urea were used. The results of this experiment showed that sunflower seeding from 28 April to 8 May gives more assurance for higher yields. According to the results of this study, early sunflower cultivars, having the highest yield and agronomic characteristics can be recommended for the similar ecological condition of our study region a short growing season and high altitude.

Sunflower (*Helianthus annuus* L.) is an oilseed crop that can be grown in different regions in different sowing dates, but all regions and sowing dates are not appropriate for the crop development. Hence, Heldwein *et al.* (2014) conducted a study to determine yield and growth characteristics of sunflower on seven sowing dates, in Santa Maria, from 2007 to 2012. Five experiments were carried out in a completely randomized factorial design with four replications. The factor "A" was monthly sowing dates from the beginning of August to February and the factor "D" was two sunflower Varity. Head diameter, maximum leaf area index, maximum height of plants, weight of thousand achenes and yield were determined. La Niña years the highest yield is reached in September sowing dates, while in El Niño years, the crop growth and yield in early sowings are affected negatively, due to heavy rainfall, soil water excess and plant disease.

Ali *et al.* (2013*)* carried out an experiment to evaluate the effect of planting date on sunflower production (*Helianthus annuus* L.). The grade factor was studied in 3 levels (Record = V_1, Zaria =V_2, Golshid =V_3) and planting date factor was studied in four levels (July 15 =D_1, July 30 =D_2, August 14 = D_3, August 29 =D_4). The results showed that the effect of grade and planting date on diameter of circular flower of *Helianthus annuus* , thousand seed weight and seed yield was significant but the mutual effect of planting date and grade on above mentioned cases was not significant. The highest seed yield and oil was 3523 and 1713 kg ha^{-1}, respectively which was related to Golshid grade and was obtained on August 14. The lowest seed yield was obtained on planting date of July 15 by grade of Zaria, which was 1900 kg seeds per hectare. Increasing yield in sowing date of August 14 is probably related to suitable climatic conditions at the time of flowering and pollination and larger number of pollinating bees and insects.

Yagoub *et al*. (2013) carried out an experiment on soybeans (*Glycine max* Merrill) genotypes G_1 (1904 E) and G_2 (1905 E) were planted on five sowing dates: S_1 (2 June), S_2 (9 June), S_3 (16 June), S_4 (23 June), and S_5 (30 June) for two seasons (2009/10-2010/11). The experiments were done in split- plot design, in semi-desert region in Sudan. In season 2009/10 the result proved that S_4 (23 June) and S_5 (30 June) obtained the lowest values of yield components. The results of season 2010/11 showed significant differences for number of pods $plant^{-1}$, number of seeds pod^{-1} and highly significant difference was gained in weight of pods $plant^{-1}$, weight of seeds $plant^{-1}$, 100-seed weight, yield and harvest index. The S_3 (16 June) mid June, obtained maximum values and S_5 (30 June) gave the lowest values of the above parameters.

Lawal *et al.* (2011) was found that planting date significantly affected all the growth and yield parameters including oil yield. As planting was delayed, seed and oil yields declined (2,513 kg ha^{-1} and 1,077 L ha^{-1}, respectively when planted on August 13 as against 1,234 kg ha^{-1} and 528 L ha^{-1} , seed and oil yields respectively, at September 10 planting in 2004. Similar result was observed in 2005; but there was a significant reduction in yields (815 kg ha^{-1} and 349 L ha^{-1}, respectively when planted on July 21 as against 216 kg ha^{-1} and 92 L ha^{-1} seed and oil yields, respectively, at September 10 planting due to change in rainfall distribution (climate) during growth period. The luxuriant growth of those planted late did not translate to seed yield because there was not sufficient water during the seed filling stage of growth. Late July till mid-August is the best planting time for optimum sunflower seed and oil yields in Ibadan. However, for successful planting, farmers must rely on meteorological weather forecast most especially that the world is experiencing climatic change phenomenon.

Alam *et al.* (2007*)* was carried out an experiment consisting of three sowing dates viz., 26 February, 10 March and 22 March and four harvesting times viz., harvesting at 30, 35, 40 and 45 days after flowering (DAF) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from February to June 1999. The maximum plant height, number of branches $plant^{-l,}$ capsules $plant^{-l}$, seeds $capsule^{-l}$, seed yield (kg ha^{-l}) and stover yield (kg ha^{-l}) were obtained from the crop sown on 26 February. Most of these parameters were statistically identical to 10 March sowing except plant height, number of branches and capsule $plant^{-l}$ but all of them were recorded significantly lowest in 22 March sowing compared to first sowing. The results also indicated that the sesame variety T6 produced the highest seed yield when sown on 26 February and harvested at 40 DAF.

Rahman *et al.* (2007) was conducted an experiment during 2002/2003 season in Northern Sudan to evaluate some promising sesame genotypes under different sowing dates (mid June, early July and mid-July). The obtained results showed that, sowing dates significantly affected no. of plants m^{-2}, number of branches & number of capsules $plant^{-1}$, 1000- seed weight and seed yield. The highest seed yield was recorded for early July sowing by Shuak genotype.

2.2 Effect of potassium

Ahmad *et al*. (2018) carried out a field experiment on influence of sulphur and potassium levels on yield and yield attributes of sesame in Agronomy Research Farm, Peshawar, and Khyber Pakhtunkhwa (KP) during Kharif season, 2017. Different levels of sulphur (0, 25, 50 and 75 kg ha^{-1}) and potassium (0, 25, 50 and 75 kg ha^{-1}) were applied to experimental plots. The results stated that sesame significantly responded to the application of sulphur and potassium up to 50 kg ha^{-1} for growth, quality, yield and yield attributes of sesame. Highest plant (76.97 cm), maximum number of branches per plant (3.93), more number of capsules per plant (42.77), more number of seeds per capsules (59.36), maximum seed yield (617 kg ha^{-1}), maximum stover yield (1043 kg ha^{-1}), more oil content (48.65 %) and maximum oil yield (286.6 kg ha^{-1}) were recorded from 50 kg ha^{-1} potassium treatments.

Adhikary *et al*. (2018) done an experiment during two consecutive Rabi seasons of 2013 and 2014 at the Krishi Vigyan Kendra Farm, Ashokenagar, and West Bengal, India to determine the effect of omitted nutrients on productivity of sunflower. The influence of nutrient omissions on the soil health was also determined. The results indicated that positive response of NPK fertilization to sunflower. Ample NPK (125% RDF) recorded maximum plant height (1.69 m), basal girth (9.08 cm) and capitulam diameter (17.15 cm) and differed significantly from other treatments. Sunflower plants produced maximum yield attributes (972.14 seeds $capitulum^{-1}$, 75.74 g seed weight $capitulum^{-1}$ and 5.84 g for 100-seed weight and seed yield (1723.27 kg ha^{-1}) of sunflower under application of N100P50K50. N actual balance in postharvest soil was positive in plots fertilized with 100% RDF (N80P40K40) and P and K-omitted plots. There was actual gain of P status of post-harvest soil in all the treatments, except P-omitted plots. However, the actual balance of K was negative irrespective of treatments.

Jyothi and Anjaiah (2018), conducted a field experiment on sandy loam soil (inceptisol) with deficint of B and medium soil available potassium. Different levels of boron and potassium with sunflower hybrid GK-2002 as test crop to study the effect B and K on sunflower performance viz., seed yields, oil content, protein content, and fatty acid composition. The seed yield varied from 952.8 to 1430 kg ha^{-1}. Higher seed yield was recorded with B1.5K60 however, it was at par with B1K30 treatment. Maximum oil content and fatty acid contents record with B1K30 and protein content was found maximum with B1.5K60 treatment. B x K interactions was found significant with seed yield. Based on the results of investigation it can be concluded that among various levels of B and K application of boron @ 1kg ha^{-1} along with recommended dose (90:60:30) of N: P: K ha1 was sufficient to get higher B: C ratio and net returns and also to prevent luxury consumption of K by sunflower crop cv. GK-2002 in sandy loam soils.

Shu-tian *et al.* (2018) carried out a field experiments in oil and edible sunflower to study the effects of potassium (K) fertilization on achene yield and quality, and to estimate the nutrient internal efficiency (IE) and nutrient requirement in sunflower production. All trials in edible sunflower and 75% trials in oil sunflower showed positive yield responses to K fertilization. Compared with control without K fertilization, the application of K increased achene yield by an average of 406 kg ha^{-1} for oil sunflower and 294 kg ha^{-1} for edible sunflower. Application of K also increased 1000-achene weight and kernel rate of both oil and edible sunflower. K fertilization also improved the contents of oil, oleic acid, linoleic acid and linolenic acid in achenes of oil sunflower, and increased contents of oil, total unsaturated fatty acid and protein in achenes of edible sunflower.

Jat *et al.* (2017) was conducted a field experiment at Agronomy farm, S.K.N. College of Agriculture, Jobner (Rajasthan) during kharif 2014 on loamy sand soil. The experiment consisted of 16 treatment combinations of four levels each of potassium (0, 25, 50 and 75 kg ha^{-1}) and sulphur (0, 20, 40 and 60 kg ha^{-1}). The results showed that progressive increase in level of potassium up to 50 kg K2O ha^{-1} and sulphur 40 kg S ha^{-1} significantly increased the quality of sesame.

Lakhan *et al*. (2017) was undertaken a field experiment on sandy loam soil during 2013-14 and 2014-15 at Panwari village of Agra (U.P.) to study the effect of potassium on yield, quality and nutrients uptake by Indian mustard (*Brassica juncea* L.). Five levels of potassium (0, 20, 40, 60 and 80 kg K_2O ha^{-1}) were evaluated in randomized block design with four replications. The results showed that the plant height, yield attributes (siliqua $plant^{-1}$, seeds $silqua^{-1}$ and test weight), seed and stover yields of mustard were significantly improved with the increase in the levels of potassium and the maximum seed yield (19.50 q ha^{-1}) and stover yields (57.77 q ha^{-1}) were recorded with 60 kg K_2O ha^{-1}. The content and yield of protein oil percentage increased significantly with increasing K doses, thus mustard fertilized with 60 kg K_2O ha^{-1} recorded the maximum yield of protein (386.1 kg ha^{-1}) and oil (766.3 kg ha^{-1}). The highest values of protein content (20.4 %) and oil content (39.3 %) were recorded with 80 and 60 kg K2O ha^{-1} respectively.

Singh *et al.* (2017) was found that application of 20 kg K^{-1} and 30 kg K ha^{-1} along with state recommended N (80 kg N ha^{-1}) and P doses (30 kg P ha^{-1}) increased the seed yield of mustard by 13.9 and 17.3%, respectively over state recommended N80P30 alone (SRDF).Yield of seed obtained with 20 and 30 kg K ha^{-1} were statistically at par during each year, implying that application of 20 kg K ha^{-1} was good enough to meet the K requirement of mustard grown on low to medium K status soils of the state. The mean N, P, K and S uptake by mustard under SRDF + K20 treatment was 7.4, 14.3, 8.2 and 13.5% higher, respectively, than that under SRDF treatment. Compared with SRDF, the Zn, Cu, Mn and Fe uptake by mustard were 8.7, 8.8, 2.8 and 1.9% more, respectively, with SRDF + K20 treatment.

Khanam *et al.* (2016) was conducted a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during December 2013 to April 2014 to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1} , P_1: 100 kg TSP ha^{-1} , P_2: 175 kg TSP ha^{-1} , P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MOP, K_1: 60 kg MOP ha^{-1} , K_2: 120 kg MOP ha^{-1} , K_3: 180 kg MOP ha^{-1}), and their combinations on growth and yield of soybean (*Glycine max*). Number of nodules $plant^{-1}$, number of filled pods $plant^{-1}$, and number of seeds pod^{-1}, 1000-seed weight, seed yield, and biological yield and harvest index increased significantly up to 175 kg ha^{-1} TSP. On the other hand, numbers of nodules $plant^{-1}$, number of filled pods $plant^{-1}$, length of pod, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield were enhanced significantly up to 120 kg ha^{-1} MOP. The treatment of combined phosphorus @ 175 kg ha^{-1} and potassium @ 120 kg MOP ha^{-1} depicted the highest number of filled pods $plant^{-1}$ (63.00), length of pod (3.16 cm), number of seeds pod^{-1} (3.11) vis a vis the highest (3.67 t ha^{-1}) seed yield. Thus, the combined application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MOP could be the optimum for getting maximum yield of soybean

Faisal *et al.* (2013) was carried out a field experiment in Thi-qar province – Batha city with two Seasons, 1st experiment was during fall season (2011) and 2nd experiment was during Spring Season (2012) using R.C.B.D design with three replications. The main objective of this experiment was to find the effect of dates and levels of Potassium on oil quality and yield of Sunflower. Six levels of K were tested (K_0= Control, K_1= 120 kg K.ha^{-1} (Soil), K_2= 6000 mg K L^{-1} foliar, K_3=30 kg K ha^{-1} soil+3000 mg K L^{-1} foliar, K_4=30 kg K ha^{-1} soil+6000 mg K L^{-1} foliar, K_5=30 kg K ha^{-1} soil +9000 mg K L^{-1} foliar) and three dates (T_1= 8 leaves, T_2= 14 leaves, T_3= 20 leaves). The results revealed that increasing of Potassium levels significantly caused increasing in (seed number, 1000-seed weight and yield plant) fall and spring seasons. The maximum seed yield was 28. 7% and it obtained by third date of 2nd season. Also the percent of oil and oil yield of 1st and 2nd season were increased respectively. The interaction of two treatment had significant effect on yield traits (seed number and seed 1000 weight) of 2nd season.

Mir *et al.* (2010) conducted a factorial randomized field experiment on mustard (*Brassica juncea* L. Czern & Coss var. Alankar) at Aligarh to study the effect of different combinations of phosphorous and potassium applied as monocalcium superphosphate and muriate of potash respectively (each at the rate of 30, 60, 90 kg P_2O_5 and K_2O ha^{-1}) on yield and yield attributes of mustard. A uniform dose of urea at the rate of 80 kg N ha^{-1} was also applied. Various yield characteristics including number of pods $plant^{-1}$, number of seed pod^{-1}, seed yield and oil yield were studied. The effect of phosphorus alone as well as in combination with potassium was significant. Treatments 60 kg P2O5 ha^{-1} and 60 kg P2O5 + 60 kg K2O ha^{-1} proved optimum and the increase in seed yield was due to increase in pods $plant^{-1}$ and seeds pod^{-1}.

Shehu *et al.* (2010) was found out that number of seeds per pod was not significantly affected by N application. Sesame height and number of branches were optimum at 22.5 kg P ha^{-1} while number of leaves, seeds per pod, seed yield and dry matter were optimum at 45 kg P ha^{-1}. K fertilizer did not significantly affect the number of branches, seeds per pod, seed yield and dry matter while number of leaves and pods were optimum at 22.5 and 45 kg K ha^{-1} respectively. Finally, application of 75 kg N ha^{-1}, 45 kg P ha^{-1} and 22.5 kg K ha^{-1} produced the highest seed yield. This pot experiment was conducted during the dry spell of 2005, in the screen house at the FAO/TCP farm of the Adamawa State

University, Mubi to assess the nitrogen, phosphorus and potassium nutrition on the productivity sesame (*Sesamum indicum* L.).

Sangakkara (1990) carried out a field experiment to study the effects of 0-120 kg K_2O ha^{-1} on growth, yield parameters and seed quality of soybean and reported that K application increased plant growth rate, flowers $plant^{-1}$, percentage pod set, seeds pod^{-1}, 100-seed weight and yield $plant^{-1}$.

CHAPTER III

MATREIALS AND METHOD

The details of different materials used and methodology followed during carried out experiment are discussed in this chapter.

3.1 Experimental Site:

A field experiment was conducted at the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during Kharif I (March – September), 2019 to study the growth and yield performance of sunflower in response to sowing date and potassium level. The experimental field is located at 230 41' N latitude and 90o 22' E longitude at a height of 8.6m above the mean sea level. It belongs to the AEZ 28, Madhupur Tract (FAO, 1988). It was Deep Red Brown Terrace soil and belonged to Nodda cultivated series. The soil was sandy loam in texture. The soil having pH ranged from 5.47 to 5.63, a member of hyperthermic Aeric Haplaquept under the order Inceptisol having only few horizons, developed under aquic moisture regime and variable temperature conditions. General characteristics of the soil are presented in Appendix I.

3.2 Climate

The experimental field was situated under Sub-tropical climate; usually the rainfall is heavy during kharif season, (April to September) and scantly in rabi season (October to March). In rabi season temperature is generally low and there is plenty of sunshine. The temperature tends to increase from February as the season proceeds towards kharif. The site where the experiment was conducted has a subtropical climate Kharif-1 season extends from March to early June. The monthly total rainfall, average temperature during the study period (March to early June) has been presented in Appendix II.

3.3 Crop / planting material

Sunflower var. BARI Surjomukhi 2 was used as experimental material. The variety was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Seeds were also collected from Bangladesh Agricultural Research Institute (BARI). Characteristics of BARI Shurjomukhi 2:

i) Plant height (cm): 125-140

ii) Stem diameter (cm): 2.0-2.8

iii) Matured head diameter (cm): 15-18

iv) 1000 seed weight (g): 65-70

v) Seed color: Black

vi) No. of seed/head: 450-650

vii) Days to flowering: 57-65 days

viii) Life cycle (days): Rabi: 100-105

Kharif: 85-90

ix) Yield (ton/ha): Rabi: 2-2.3

Kharif: 1.5-1.8

x) Oil content (%): 42-44 %

xi) Disease resistance: *Alternaria* Leaf blight tolerant

3.4 Treatments

Four level of sowing date and three level of potassium were used in this experiment. These are-

Factor A: Four sowing date-

S_1- 21 March

S_2- 21 April

S_3- 22 May

S_4- 22 June

Factor B: Three level of potassium-

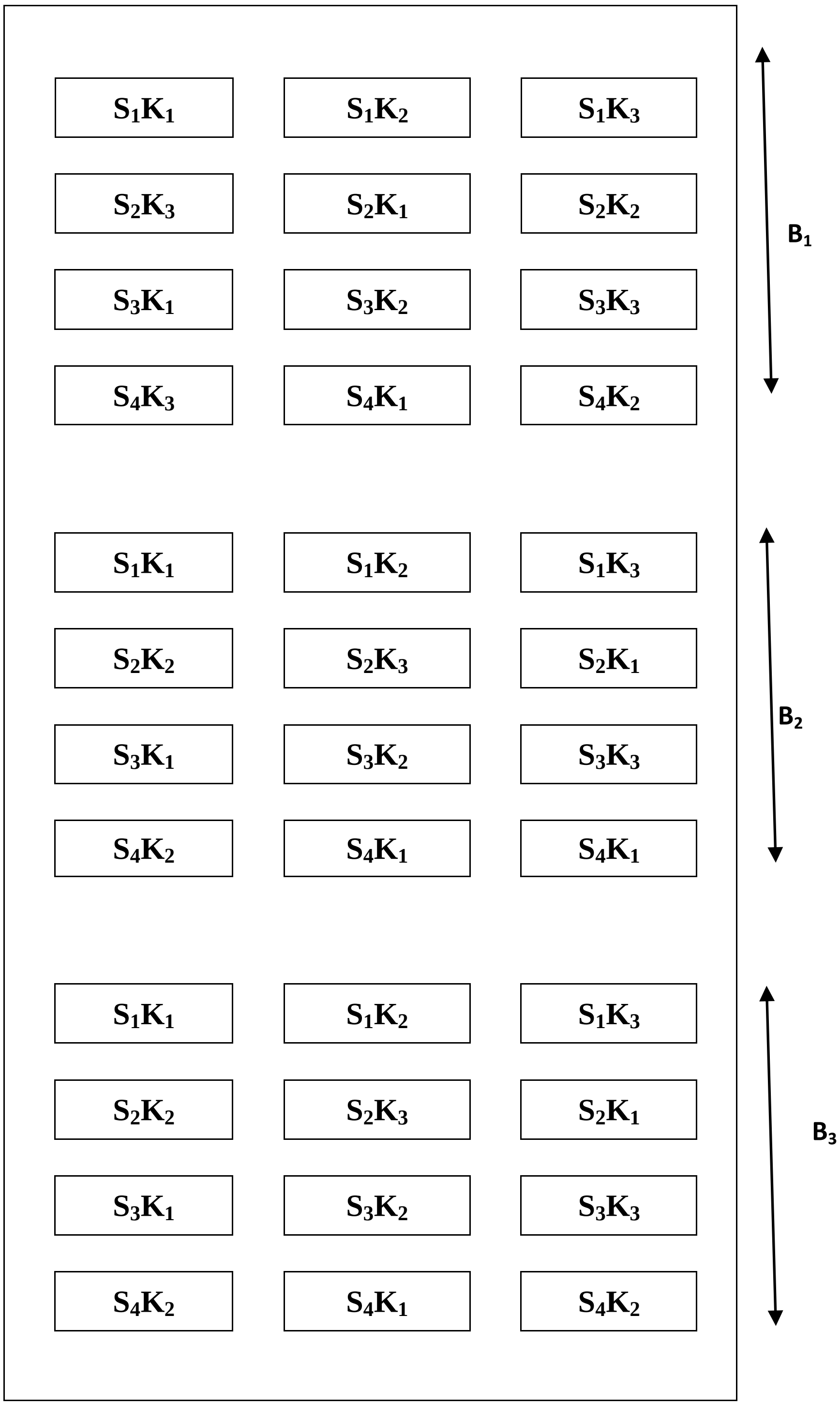
K_1- Recommended potassium (84 kg K ha^{-1})

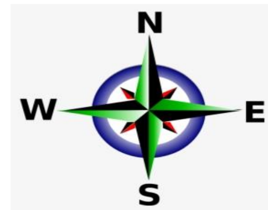
K_2- 25% increase of recommended potassium (105 kg K ha^{-1})

K_3- 50% increase of recommended potassium (126 kg K ha^{-1})

3.5 Design of experiment

The experiment was laid out in Split Plot-Design with 3 replications. Sowing date considered to main plot and potassium level as subplot. The size of unit plot was 2 m x 2 m. The total number of treatment combinations were 12 and the number of plots were 36. The treatment factors were assigned as the layout provided at the next page.





Total area: 210 m^2

Plot size: 2×2 m^2

Spacing: 50×25 cm

(R-R×P-P)

Plot to plot distance: 50 cm

Block to block distance: 50 cm

Drain: 50 cm

3.6 Land preparation

The experimental land was ploughed with a tractor followed by harrowing to attain a desirable filth. All stubbles and uprooted weeds of the previous crop were removed from the experimental field. The land was finally prepared with power tiller to ensure a good land preparation. The land was leveled by tractor drawn leveler.

3.7 Fertilizer application

Urea, TSP, gypsum, zinc sulphate and boric acid at the rate of 200 kg, 180 kg, 170 kg, 10 kg and 12 kg per hectare, respectively were applied in all plot. Potassium were applied as per treatment from MOP, where the recommended dose of MOP was 170 kg ha^{-1}. Full amount of TSP, MOP, gypsum, zinc sulphate and boric acid and half amount of urea were applied at the final land preparation. The rest amount of urea was given in two split, one at 20-25 days after emergence (DAE) and another at 40-45 DAE (before flowering). All fertilizer were applied according to (Azad *et al.* 2017).

3.8 Sowing

Seeds were treated with Vitavex-200 at the rate of 3 g kg^{-1} of seeds before sowing. Seeds were sown on 21 March, 21 April, 22 May and 22 June, 2019 according to treatment. Seeds were sown in solid lines and 3-8 cm depth. Line to line and plant to plant distance were 50 and 25 cm, respectively. Three to five seeds were sown per hill. Missing hills were sown with seeds to maintain desired plant population. Finally 1 plant $hill^{-1}$ was kept.

3.9 Cultural practices

3.9.1 Gap filing

The desired population density was maintained by thinning plants 8 days after emergence. Dead, deformed, injured and weak seedlings were replaced by new vigorous seedlings from the stock kept on the border line of the experiment.

3.9.2 Weeding

Weed control is critical for its early stage of growth up to 30-35 days. Two hand weeding's were done at 20-25 DAE and 45-50 DAE for realizing potential yield.

3.9.3 Irrigation

Three irrigation was given at 40 DAS (before flowering), 50 DAS (flower formation) and 70 DAS (grain formation).

3.9.4 Insects and diseases

Leaf blight of sunflower was noticed in S_1 (21 March -10 June). First dose of Ridomil gold 1ml /l water was applied 57 days after sowing (DAS). Other 2 doses were applied at 7 days interval.

3.10 Harvesting

Harvesting was done when 90% back of sunflower head turned yellow –brown in color and the upper leaves on the stem turned brown. The crop was harvested from an area of $1m^2$ from each plot. The data on agronomic parameters and yield components of sampled plants were recorded. The harvested plants were segmented into components such as straw (leaf and stem together) and seed. The straw and head of sunflower plant were then dried in the sun. The seeds were dried in the sun and weighed. The seed weight was adjusted at 8% moisture content.

3.11 Data collection and sampling procedure

Five plants were selected randomly from 2^{nd} and 3^{rd} rows and were tagged for data collection. The 1st and 4^{th} rows were not selected to avoided border effect. The sample plants were uprooted and dried in the sun properly. The data were collected on the following parameters.

3.11.1 Plant height

Plant height was measured in centimeter (cm) by a meter scale at 20, 40, 60 and 80 days after sowing (DAS) from ground level to the tip of the plant.

3.11.2 Dry matter of leaf, stem, and reproductive parts

Five plants were collected from the line. The plants were divided into leaf, stem and reproductive organs and dried in the oven until a constant level. Then dry weight was measured in gram by an electric balance.

3.11.3 Days to head initiation

Days to head initiation considered when emergence of 80% head of the plants within a plot were taken place. The number of days for 80% head initiation was recorded.

3.11.4 Days to maturity

Days to maturity considered when 80% head of the plants turn yellow-brown in color within a plot. The number of days to attain maturity was recorded.

3.11.5 Head diameter

Head diameter was recorded in several directions with a meter scale at matured stage from five randomly selected plants and measured in centimeter (cm) and each of plant was measured separately.

3.11.6 Number of seed plant^{-1}

Five plants were taken from each sample and count seed of each head. The mean no. of seed was taken.

3.11.7 Weight of 1000-seed

One thousand cleaned seeds were dried in the sun and weighed by a digital electric balance at the stage the grain retained 12% moisture The weight were expressed in gram.

3.11.8 Seed yield plant^{-1}

Five plants were selected from each sample and seeds were separated from each head. Then seed were dried in the sun and weighed by using an electric balance in gram. The mean weight was taken.

3.11.9 Seed yield ha^{-1}

Seed yield of 1m^2 was measured and it was converted to yield per hectare. It was expressed in ton.

3.11.10 Stover yield ha^{-1}

Stover yield of 1m^2 was measured and it was converted to yield per hectare. It was expressed in ton. Without seed, other parts of plants such as stem, leaf, head was counted as stover yield.

3.11.11 Biological yield

Biological yield was calculated by using the following formula:

Biological yield = Grain yield + stover yield

3.11.12 Harvest index

It denotes the ratio of economic yield to biological yield and was calculated with following formula (Gardner *et al*., 1985).

$$\textbf{Harvest index} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.12 Statistical analysis

The collected data on various parameters were statistically analyzed using statistix-10 package program. The mean for all the treatments were calculated and analyses of variances of all the characters were performed by F-variance test. The significant of difference between the pairs of treatment means were evaluated by the least significant difference (LSD) test at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

Effect of sowing date and potassium on different growth, yield and yield contributing characters of sesame have been presented and discussed in this chapter. Effect of different sowing date, potassium and their interactions on growth, yield contributing characters and yield of sunflower have been presented in different tables and figures.

4 .1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of sowing date

Plant height of sunflower was significantly influenced by sowing date (Figure 1). The progressive increase of plant height was about similar for all treatments up to 20 DAS but at 40, 60 DAS and 80 DAS, S_1 (21 March) showed the highest plant height and that were 29.42, 99.08, 125.62, 141.60 cm respectively. On the other hand the lowest plant height at 40 DAS was found to S_2 (21 April) that was 45.98 cm which was identically similar to S_3 (22 May) and the lowest plant height at 60 DAS in S_3 (22 May) that was 106.72cm.The lowest plant height at 80 DAS was found in S_4 (22 June) that was 118.72cm, which was statistically similar to S_3 (22 June).This might be weather variation and favorable environment was found in S_1 (21 March)

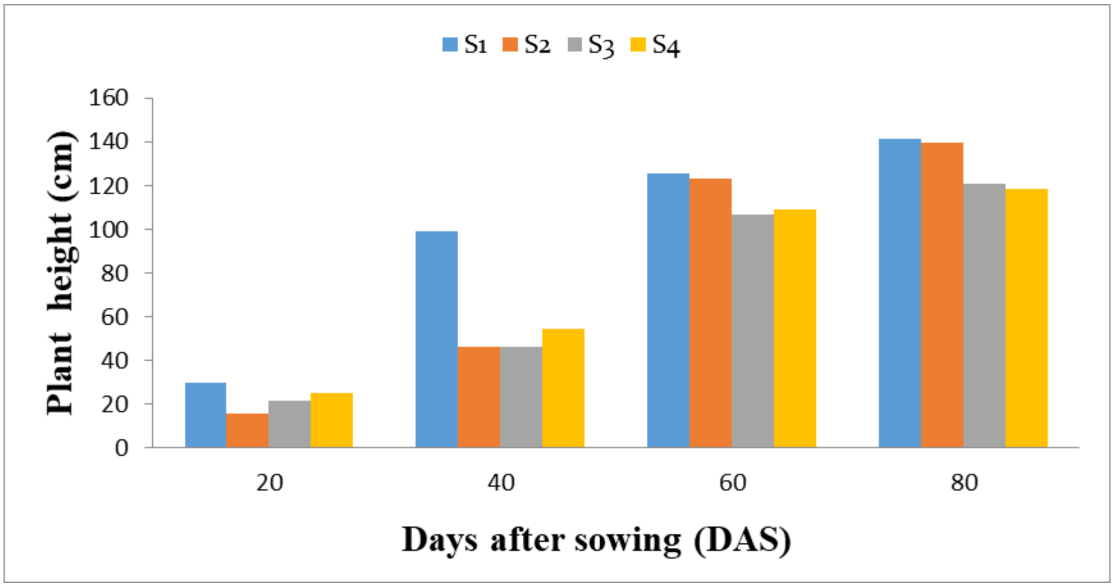
4.1.1.2 Effect of potassium

Plant height of sunflower showed significantly variation by different potassium level (Figure 2). The highest plant height was 23.66 and 63.14cm at 20 and 40 DAS from K_2 (105 kg K ha^{-1}). On the other hand, the maximum plant at 60 and 80 DAS were 116.87, 131.43cm from K_3 and K_2 respectively. The minimum plant height at 20, 60, 80 DAS were 22.29, 115.30, 127.82cm from K_1 (84 kg K ha^{-1}) but K_3 (126 kg K ha^{-1}) showed lowest plant height (59.65cm) at 40 DAS.. It was revealed that as a necessary element of potassium for the growth and development of sunflower and with the increase of potassium fertilizer, plant height increased up to a certain level then decreases. This might be due to the reason that high root shoot ratio is associated with potassium uptake. Similar result were observed by Adhikary *et al.* (2018).

Nita *et al*. (2002) reported that plant height increased with increasing rates of potassium in soybean. Sangakkara *et al*. (2001) also found that potassium increased shoot growth and as a significant factor in overcoming soils moisture stress in tropical cropping systems in soybean.

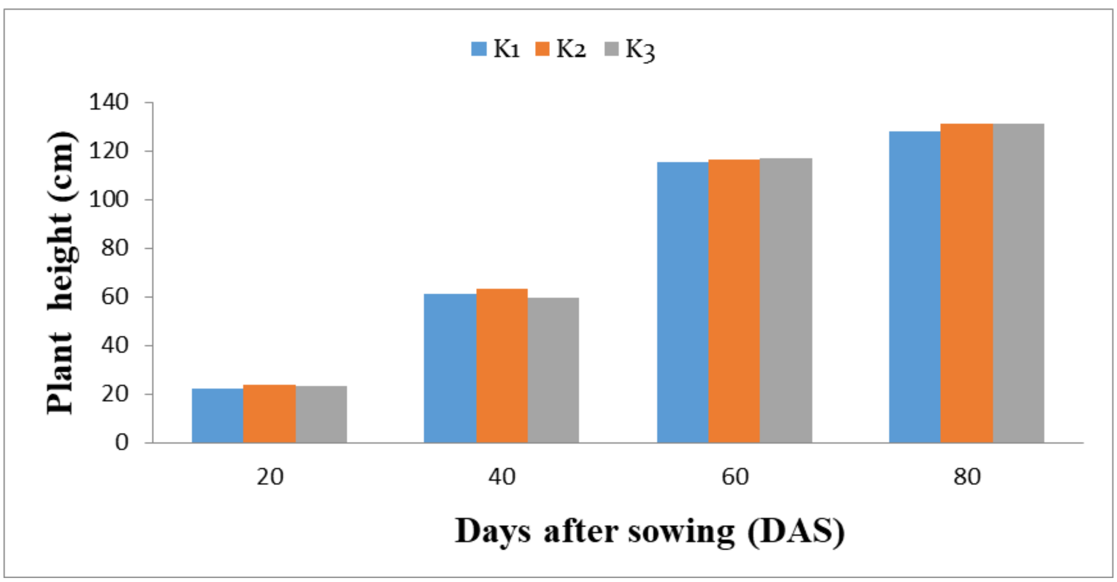
4.1.1.3 Combined effect of sowing date and potassium

The interaction effect of sowing date and potassium on plant height was significant at different days after sowing (Table 1). It was observed that the highest plant height was recorded in the treatment combination of S_1K_2 (29.89, 99.99, 127.40 and 142.67cm, respectively) which was not significantly different from S_1K_3 and significantly similar with S_2K_3 at 60 and S_1K_1, S_2K_2, S_2K_3 at 80 DAS. On the other hand the lowest plant height (15.22, 42.66, 106.67, 115cm at 30, 40, 50, 60, 80 DAS was recorded in the treatment combination of S_2K_1, S_3K_3, S_4K_3 and S_4K_1 respectively which was not significantly different from S_3K_2, S_3K_1 at 60 DAS and significantly similar with S_1K_1, S_3K_3, S_3K_2 at 80 DAS and S_1K_1, S_2K_3 at 40 DAS and 60 DAS. It was revealed that treatment combination of S_1K_2 is helpful to increase plant height of sunflower.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 =22 June

Figure 1. Effect of sowing date on plant height of sunflower at different days after sowing (DAS) (LSD $_{(0.05)}$ = 0.51, 1.99, 1.71 and 3.13, respectively at 20, 40, 60 and 80 DAS).



K_1 = Recommended K (84 kg K ha$^{-1)}$, K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 2. Effect of potassium level on plant height of sunflower at different DAS (LSD $_{(0.05)}$ = 0.35, 1.63, 1.26 and 2.26, respectively at 20, 40, 60 and 80DAS).

Table 1. Combined effect of sowing date and potassium level on plant height of sunflower at different days after sowing (DAS)

Treatment Combination	Plant height (cm)			
	20DAS	40DAS	60DAS	80DAS
S_1K_1	28.67 b	99.46 a	123.40 b	140.47 a
S_1K_2	29.87 a	97.83 a	126.07 a	141.67 a
S_1K_3	29.70 a	99.93 a	127.40 a	142.67 a
S_2K_1	15.23 h	46.26 fg	121.53 b	134.60 b
S_2K_2	15.97 g	47.86 ef	121.97 b	141.37 a
S_2K_3	15.47 gh	43.80 gh	126.27 a	142.00 a
S_3K_1	20.87 f	46.26 fg	106.90 de	121.00 cd
S_3K_2	23.20 e	49.93 de	106.13 e	119.67 c-e
S_3K_3	21.13 f	42.66 h	107.13 de	122.00 cd
S_4K_1	24.40 d	53.40 c	109.35 cd	115.23 e
S_4K_2	25.60 c	56.93 b	111.20 c	123.00 c
S_4K_3	25.60 c	52.20 cd	106.67 e	117.33 de
$LSD_{(0.05)}$	0.71	3.26	2.52	4.53
CV (%)	1.78	3.07	1.25	2.01

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

K_1 = Recommended K (84 kg K $ha^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

4.1.2 Stem dry matter weight

4.1.2.1 Effect of sowing date

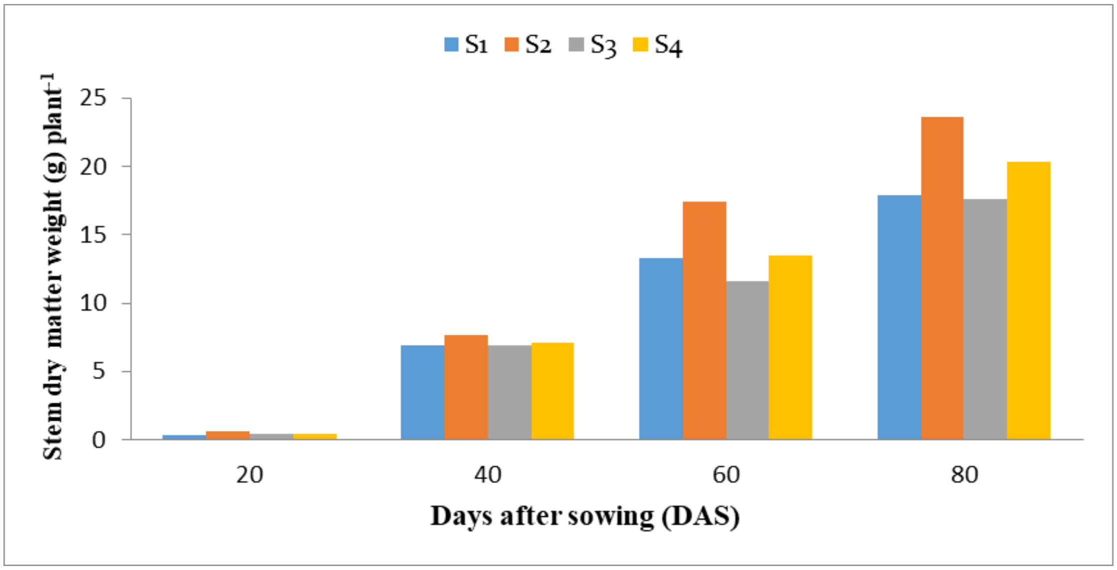
Dry matter weight of stem was significantly influenced by sowing date (Figure 3 and Appendix IV).The maximum dry matter weight of stem observed in S_2 (21 April) at 20, 40, 60,80 DAS that were 0.62, 7.67, 17.41 and, 23.64 gm, respectively. The minimum dry matter weight of stem at 20 DAS was 0.33 gm. in S_1 (21 March) and S_3 showed at 40, 60, 80 DAS (6.90, 11.64, 17.60 gm. respectively) which was identically similar with S_1 at 80 DAS. The results obtained from S_4 (22June)) showed intermediate results compared to all other treatments. This might be climate variation. The stable temperature, soil moisture helped to increasing dry weight of stem.

4.1.2.2 Effect of potassium

Potassium affected dry matter of stem of sunflower significantly at different days after sowing (Figure 4 and Appendix IV). It was observed that at 20, 40 DAS K_2 (21 April) showed highest dry weight of stem (0.48, 7.76 gm.). On the other hand, at 60, 80 DAS; K_3, K_2 showed highest dry weight of stem that were 14.34 and 21.11 gm, respectively which was statistically with K_2 (21 April) at 60 DAS. The lowest dry matter weight; 0.41, 13.51, 18.89 gm. respectively was recorded at 20, 60, 80 DAS, respectively with K_1 (21 March). On the other hand K_3 showed the lowest dry of stem at 40 DAS (6.73 gm.) which was not significantly different from K_1 at 40DAS.This result revealed that dry matter of stem increasing with the increasing of potassium.

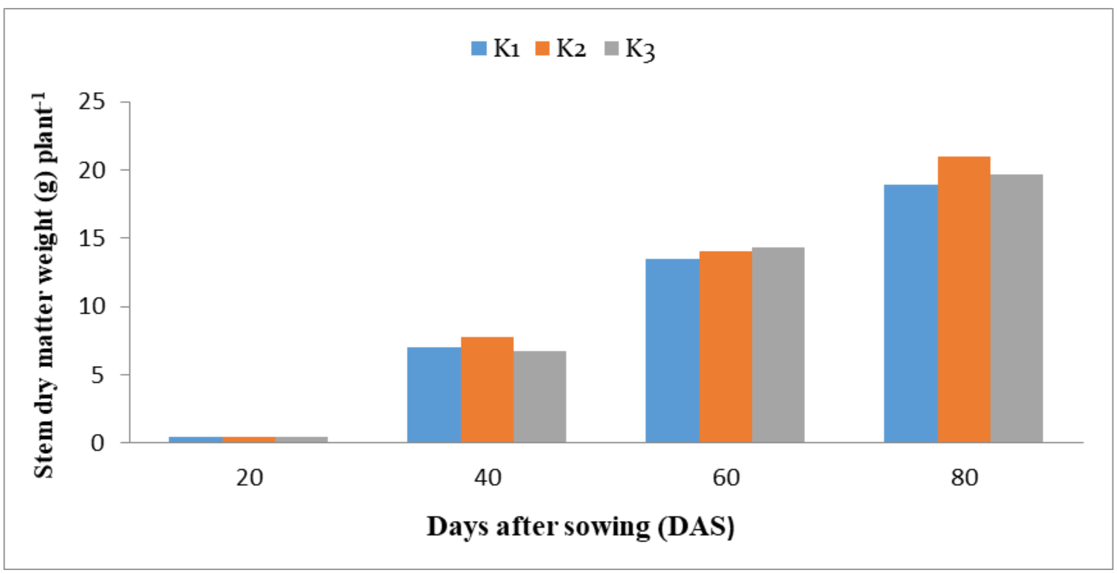
4.1.2.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on dry weight of stem had significant effect at different days after sowing (Table 2 and Appendix IV). It was observed that the highest dry weight of stem at 20, 40, 60 and 80 DAS was recorded with the treatment combination of S_2K_2 (0.73, 8.73, 18.83 and 24.93, respectively). On the other hand the lowest dry weight of stem (0.26, 6.30, 12.73 ,24.20 g) at 20, 40, 60 and 80 DAS, respectively was recorded with the treatment combination of S_1K_1, S_4K_3, S_3K_3 and $S_3K_{3,}$ respectively which was not significantly different form S_1K_1 at 20,40 and 60 DAS and significantly similar with S_3K_1 at 40 and 80 DAS and also similar with S_3K_3,S_4K_2 at 40 and 60 DAS, respectively and all other treatment combinations significantly different from highest and lowest result.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 3. Effect of sowing date on stem dry matter weight of sunflower at different DAS ($LSD_{0.05}$ = 0.03, 0.43, 0.43 and 0.59, respectively at 20, 40, 60 and 80 DAS).



K_1 = Recommended K (84 kg K ha$^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 4. Effect of potassium level on stem dry matter weight of sunflower at different DAS ($LSD_{0.05}$ = 0.02, 0.31, 0.31 and 0.41 respectively at 20, 40, 60 and 80 DAS).

Table 2. Combined effect of sowing date and potassium level on stem dry matter weight of sunflower at different days after sowing (DAS)

Treatments Combination	Stem dry matter weight (g) plant^{-1}			
	20DAS	40DAS	60DAS	80DAS
S_1K_1	0.26 e	6.87 c-e	13.33 e-g	17.33 f
S_1K_2	0.31 e	7.30 bc	13.67 e	18.67 e
S_1K_3	0.41 d	6.57 de	13.00 fg	17.67 f
S_2K_1	0.56 b	7.07 cd	16.10 c	22.90 b
S_2K_2	0.73 a	8.73 a	18.83 a	24.93 a
S_2K_3	0.56 b	7.20 cd	17.30 b	23.10 b
S_3K_1	0.39 d	6.87 c-e	11.20 h	16.38 g
S_3K_2	0.40 d	6.97 cd	11.00 h	20.23 d
S_3K_3	0.37 d	6.87 c-e	12.73 g	16.20 g
S_4K_1	0.37 d	7.11 cd	13.40 ef	18.98 e
S_4K_2	0.49 c	7.86 b	12.80 fg	20.20 d
S_4K_3	0.37 d	6.30 e	14.33 d	21.87 c
$LSD_{(0.05)}$	0.05	0.62	0.618	0.82
CV (%)	6.25	5.00	2.56	2.38

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1= 21 March, S_2 = 21 April, S_3= 22 May, S_4 = 22 June

K_1= Recommended K (84 kg K ha$^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

4.1.3. Leaf dry matter weight

4.1.3.1 Effect of sowing date

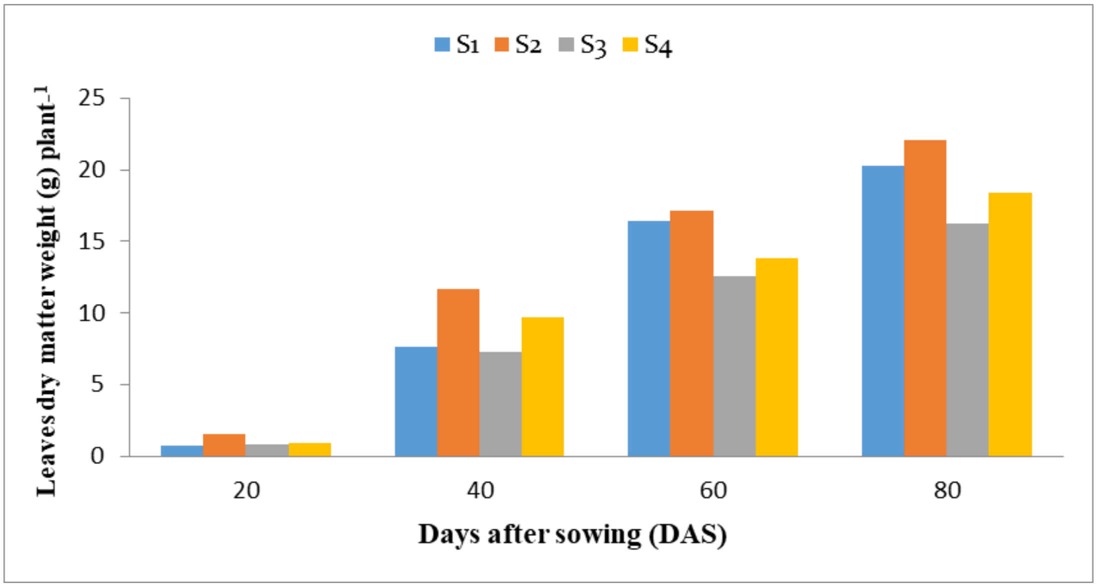
Dry matter weight of leaf was significantly influenced by sowing date of the plants (Figure 5). It was observed that at 20, 40, 60 and 80 DAS; S_2 (21 April) showed the highest leaf dry matter weight and that were 1.58, 11.70, 17.16 and 22.04 g respectively. On the other hand, the lowest leaf dry matter weight; 7.24, 12.58, 16.28 g was recorded at 40, 60 and 80 DAS with S_3 (22 May) but S_1 (21 March) showed lowest dry weight at 20 DAS (0.70 g). This might be due to temperature, soil moisture and rainfall variation in different sowing date.

4.1.3.2 Effect of potassium

Potassium had significant influence on dry weight of leaf at different days after sowing (Figure 6). It was observed that at 20, 40, 60 and 80 DAS treatment K_3 (126 kg K ha^{-1}) showed maximum leaf dry matter weight (1.55, 9.66, 16.48 and 19.72 g respectively) which was statistically similar with K_1 at 80 DAS. On the other hand, the lowest leaf dry matter weight (0.63, 8.43, 13.62 and 18.42 g) respectively was recorded at 20, 40, 60 and 80 DAS respectively with K_1 (84 kg K ha^{-1}). The obtained result indicate that leaf dry matter weight increasing with potassium increase. This might be potassium increase the leaf expansion.

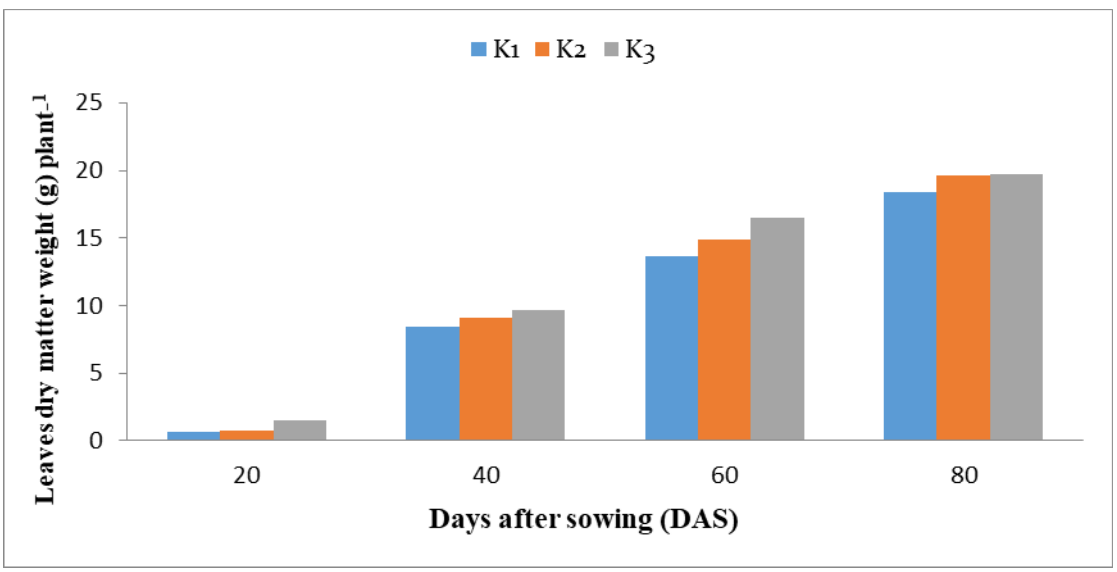
4.1.3.3 Combined effect of sowing date and potassium

The interaction effect of sowing and potassium on leaf dry matter weight had significant effect at different days after sowing (Table 3). It was observed that the maximum leaf dry matter weight at 20, 40, 60 and 80 DAS was recorded with the treatment combination of S_2K_3 (2.35, 12.67, 19.47 and 22.33 g respectively) but not significantly different from S_2K_1 and S_2K_2 at 80 DAS. On the other hand the lowest leaf dry matter weight (0.42, 6.37, 11.30 and 14.93 g) at 20, 40, 60 and 80 DAS respectively was recorded with the treatment combination of S_3K_1 which was similar with S_1K_1 at 20 DAS. The results obtained from all other treatment interaction were significantly different compared to highest and lowest results.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 5. Effect of sowing date on leaf dry matter weight of sunflower at different DAS ($LSD_{0.05}$ = 0.08, 0.35, 0.44 and 0.76 respectively at 20, 40, 60 and 80DAS).



K_1 = Recommended K (84 kg K $ha^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 6. Effect of potassium level on leaf dry matter weight of sunflower at different DAS ($LSD_{0.05}$ = 0.06, 0.26, 0.31 and 0.34 respectively at 20, 40 60 and 80 DAS).

Table 3. Combined effect of sowing date and potassium level on leaf dry matter weight of sunflower at different days after sowing (DAS)

Treatment Combination	Leaf dry matter weight (g) plant^{-1}			
	20DAS	40DAS	60DAS	80DAS
S_1K_1	0.46 fg	7.17 f	15.47 de	19.67 c
S_1K_2	0.67 e	7.83 e	15.67 d	20.67 b
S_1K_3	0.96d	7.98 e	18.23 b	20.47 b
S_2K_1	1.07 d	10.67 c	15.00 ef	21.83 a
S_2K_2	1.26 c	11.77 b	17.00 c	21.97 a
S_2K_3	2.35 a	12.67 a	19.47 a	22.33 a
S_3K_1	0.42 g	6.37 g	11.30 j	14.93 e
S_3K_2	0.51 fg	7.23 f	12.96 hi	16.90 d
S_3K_3	1.42 b	8.13 e	13.47 gh	16.97 d
S_4K_1	0.58 ef	9.55 d	12.70 i	17.23 d
S_4K_2	0.67 e	9.67 d	13.97 g	18.97 c
S_4K_3	1.45 b	9.87 d	14.73 f	19.10 c
$LSD_{(0.05)}$	0.11	0.50	0.61	0.69
CV (%)	6.55	3.20	2.35	2.04

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

K_1 = Recommended K (84 kg K ha$^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

4.1.4 Dry matter weight of reproductive part (Head)

4.1.4.1 Effect of sowing date

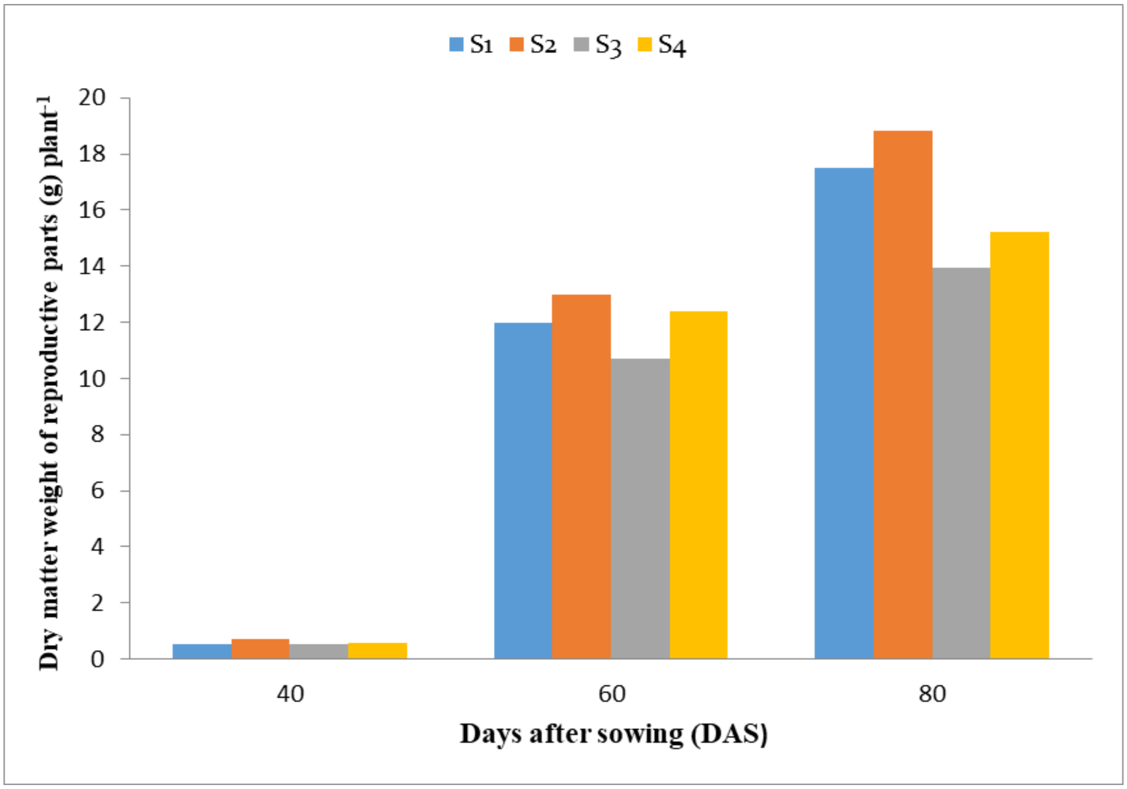
Dry weight of reproductive organ (head) was significantly influenced by sowing date of the plants (Figure 7) of sunflower. It was observed that S_2 (21 April) showed the highest dry weight of head (0.69, 13.00 and 18.84 g) at 40, 60 and 80 DAS. On the other hand, the lowest dry weight of reproductive part (head); 0.517,10.72 and 13.95 g was recorded, at 40, 60 and 80 DAS respectively with S_3 (22 May). Early sowing 21 March showed intermediate result compare to all other treatments.

4.1.4.2 Effect of potassium

Dry weight of reproductive organ (head) was significantly influenced by different potassium level (Figure 8). It was observed that at 40, 60, and 80 DAS, treatment K_2 (105 kg K ha^{-1}) showed the highest dry weight of reproductive part (0.65, 12.58 and 16.55 g) respectively. On the other hand, the lowest dry weight of reproductive part (head); 0.54 and 11.48 g respectively was recorded at 40 and 60 DAS respectively with K_1 (84 kg K ha^{-1}) but K_3 showed the lowest dry weight (16.19 g) at 80 DAS . This result indicate that potassium increase dry matter of reproductive part at a certain level then decrease.

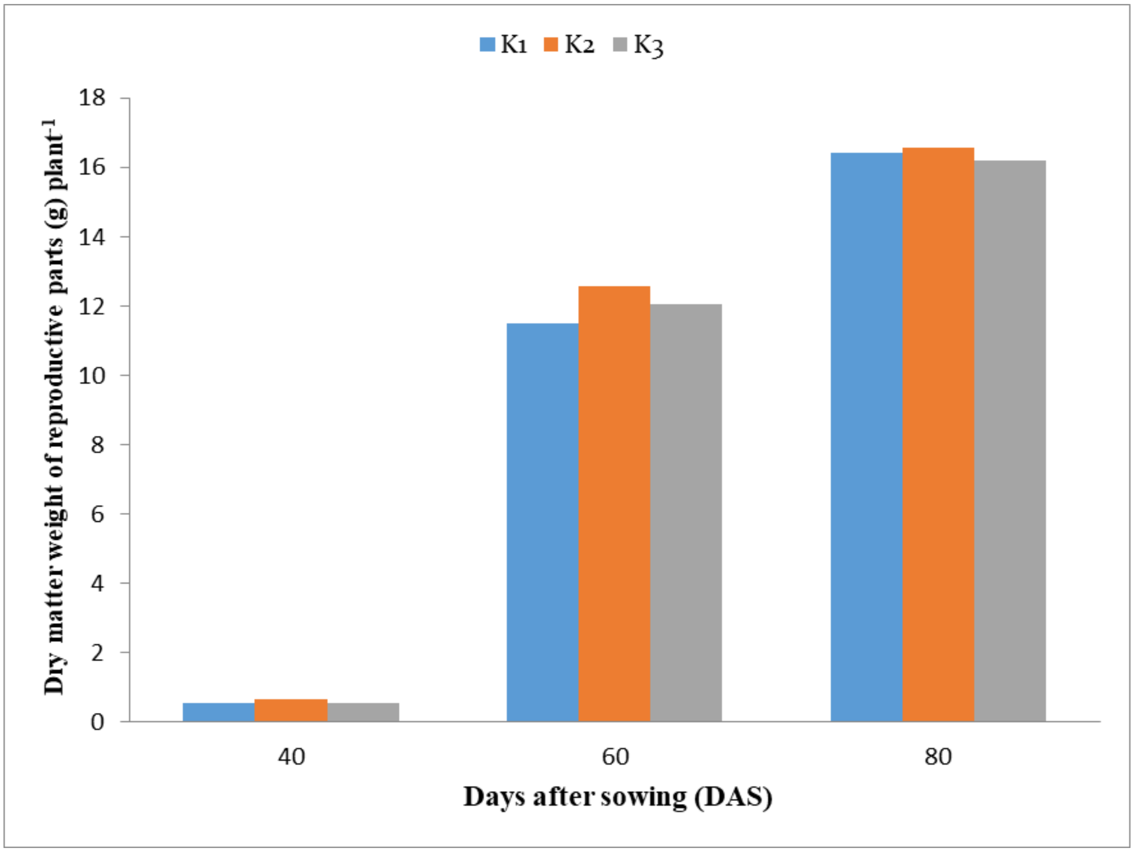
4.1.4.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on dry weight of reproductive part (head) had significant effect at different days after sowing (Table 4). It was observed that the maximum dry weight of reproductive part (head) at 40, 60 and 80 DAS was recorded with the treatment combination of S_2K_2 (0.74a 13.50a 19.46a g respectively) but identical to S_2K_3 and S_1K_2 at all above mentioned stages respectively. On the other hand, the lowest dry weight of reproductive part (head), 0.46 and 10.73 g at 40 and 60 DAS, respectively was recorded with the treatment combination of S_4K_3 which was significantly similar with S_3K_3 at 20 and S_3K_2 and S_3K_1 at 60 DAS. But S_3K_2 showed the lowest dry weight of reproductive part (13.50 g) at 80 DAS which was significantly similar with S_3K_3. The results obtained from all other treatment combinations were significantly different compared to highest and lowest results.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 7. Effect of sowing date on dry matter weight of reproductive parts (Head) of sunflower at different DAS ($LSD_{0.05}$ = 0.05, 0.59, and 0.41, respectively 40, 60 and 80 DAS).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K(126 kg K ha^{-1})

Figure 8. Effect of potassium level on dry matter weight of reproductive parts (Head) of sunflower at different DAS ($LSD_{0.05}$ = 0.04, 0.41, and 0.22, Respectively 40, 60 and 80 DAS).

Table 4. Combined effect of sowing date and potassium level on dry matter weight of reproductive parts of sunflower at different days after sowing (DAS)

Treatment Combination	Dry matter of reproductive parts (g) $plant^{-1}$		
	40DAS	60DAS	80DAS
S_1K_1	0.46 g	11.33 ef	16.59 c
S_1K_2	0.69 ab	13.33 ab	18.99 a
S_1K_3	0.48 fg	11.33 ef	16.94 c
S_2K_1	0.60 c	12.00 cde	17.79 b
S_2K_2	0.76 a	13.50 a	19.46 a
S_2K_3	0.73 a	13.50 a	19.26 a
S_3K_1	0.52 def	10.73 f	15.25 e
S_3K_2	0.57 cde	10.97 f	13.50 g
S_3K_3	0.47 fg	10.47 f	13.08 g
S_4K_1	0.58 cd	11.87 de	16.01 d
S_4K_2	0.62 bc	12.53 bcd	14.25 f
S_4K_3	0.49 efg	12.83 abc	15.47 e
$LSD_{(0.05)}$	0.07	0.82	0.44
CV (%)	7.07	3.93	1.56

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 =22 June

K_1 = Recommended K (84 kg K $ha^{-1)}$; K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

4.2. Reproductive phenomena

4.2.1 Days to head initiation (80%)

4.2.1.1 Effect of sowing date

Days to head initiation significantly affected by different sowing date of sunflower (Figure 9). Delayed head initiation (38.89 days) was noticed in S_3 (22May) which was statistically similar with S_4 (22 June) and the earliest (35.33 days) was noticed in S_1 (21 March). The results indicated that S_1 gave early head initiation and S_3 gave late one. This might be due to different climatic effect in different sowing date.

4.2.1.2 Effect of potassium

Days to head initiation (80%) significantly affected by potassium level (Figure 10). Delayed period (38.25 days) was noticed in K_3 (105 kg K ha^{-1}), which was statistically similar with K_1 (126 kg K ha^{-1}) and the earliest period (36.83 days) was noticed in K_2 (105 kg K ha^{-1}). The results indicated that K_2 (105 kg K ha^{-1}) gave early head initiation and K_3 (126 kg K ha^{-1}) gave late one. It revealed that potassium is effective for reduce maturity days.

4.2.1.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on days to head initiation (80%) was significant (Table 5). Most delayed period (39.67 days) was noticed in S_3K_3 which was not statistically different from S_2K_3, S_3K_2 and S_4K_3.On the other hand, the earliest (34.00 days) was noticed in S_1K_2. It indicated that S_3K_3 combination is superior for days to head initiation (80%) than all other treatment combination.

4.2.2 Days to maturity (80%)

4.2.2.1 Effect of sowing date

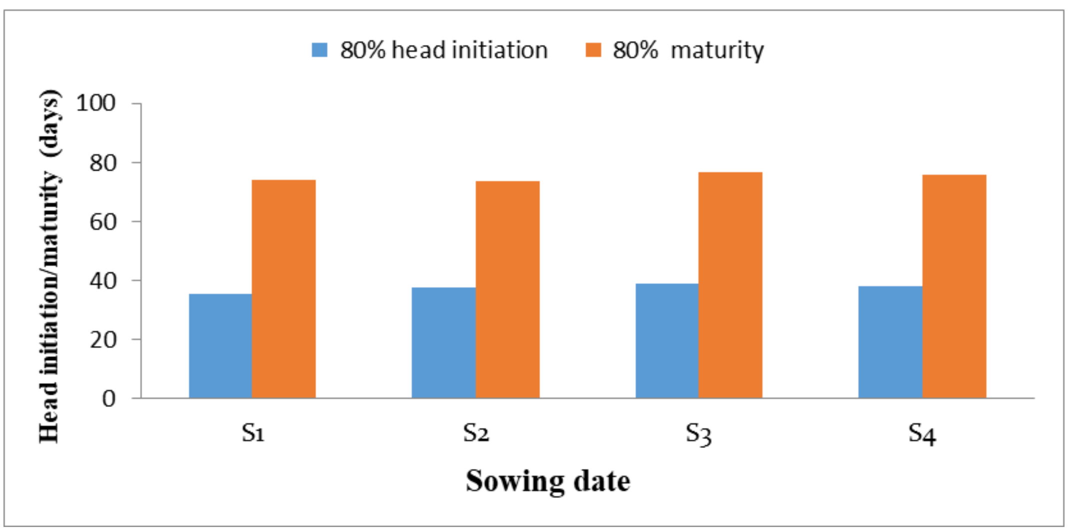
Days to maturity significantly affected by different sowing date of sunflower (Figure 9). Most delayed period was noticed in S_3 (22 May) that was 76.67 days, which was statistically similar with S_4 (22 May). On the other hand, the earliest period was noticed in S_2 (21 April), which was not significantly different from S_1 (73.78 days). The results indicated that S_1 and S_2 gave early flowering compare to S_3 and S_4, which again indicated that stable temperature helpful for early maturity.

4.2.2.2 Effect of potassium

Days to maturity (80%) significantly affected by potassium level (Figure 10). Most largest period 75.83 days was noticed in K_3 (126 kg K ha^{-1}), which was statistically similar with K_1 (105 kg K ha^{-1}). On the other hand, the earliest period (74.50 days) was noticed in $K_{2.}$ The results indicated that K_2 gave early maturity compare to K_1 and $K_{3.}$

4.2.1.3 Combined effect of sowing date and potassium

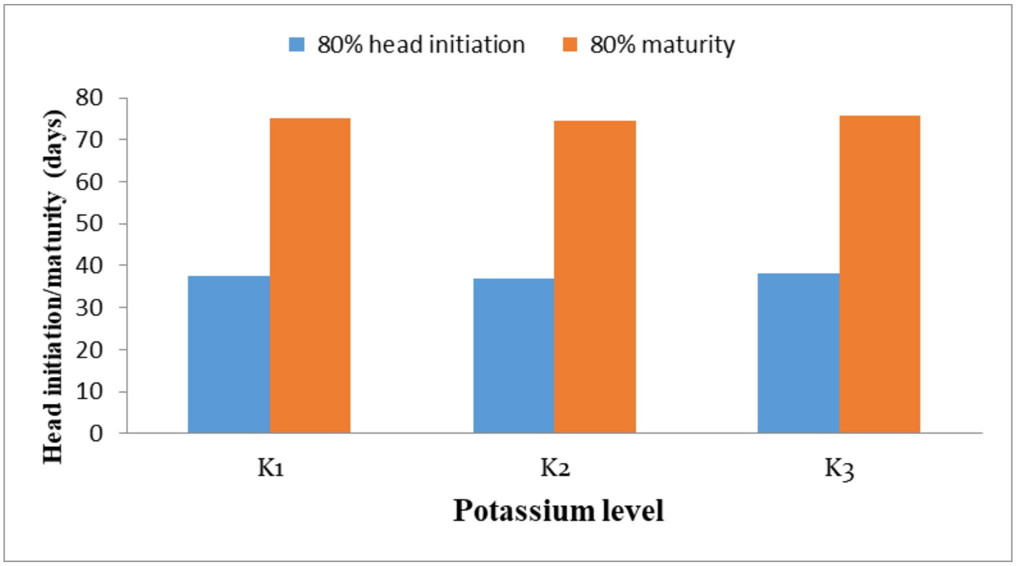
The combined effect of sowing date and potassium on days to maturity (80%) shown in Table 5. Most delayed period (78.00 days) was noticed in S_3K_3. On the other hand the shortest period (78.00 days) was noticed in S_2K_2 which was not significantly different from S_2K_1 and S_2K_2. It indicates that S_2K_2 combination is superior for days to maturity (80%) than all other treatments.



S_1= 21 March, S_2 = 21 April, S_3 = 22 May, S_4=22 June

Figure 9. Effect of sowing date on days to head initiation and days to maturity of

sunflower ($LSD_{0.05}$ = 0.79 and 1.02 respectively).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 10. Effect of potassium level on days to head initiation and days to maturity of sunflower ($LSD_{(0.05)}$ = 0.56 and 0.71 respectively).

Table 5. Combined effect of sowing date and potassium level on days to head initiation

and days to maturity of sunflower

Treatment Combination	Days to	
	Head initiation	Maturity
S_1K_1	36.67d	75.33b
S_1K_2	34.00f	72.67d
S_1K_3	35.33e	74.67bc
S_2K_1	37.67cd	73.33cd
S_2K_2	36.67d	73.33cd
S_2K_3	39.00ab	74.67bc
S_3K_1	38.33bc	76.00b

S_3K_2	38.67abc	76.00b
S_3K_3	39.67a	78.00a
S_4K_1	37.67cd	76.00b
S_4K_2	38.00bc	76.00b
S_4K_3	39.00ab	76.00b
$LSD_{(0.05)}$	1.12	1.41
CV (%)	1.72	1.09

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June
K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

4.3. Yield contributing parameter

4.3.1 Head Diameter

4.3.1.1 Effect of sowing date

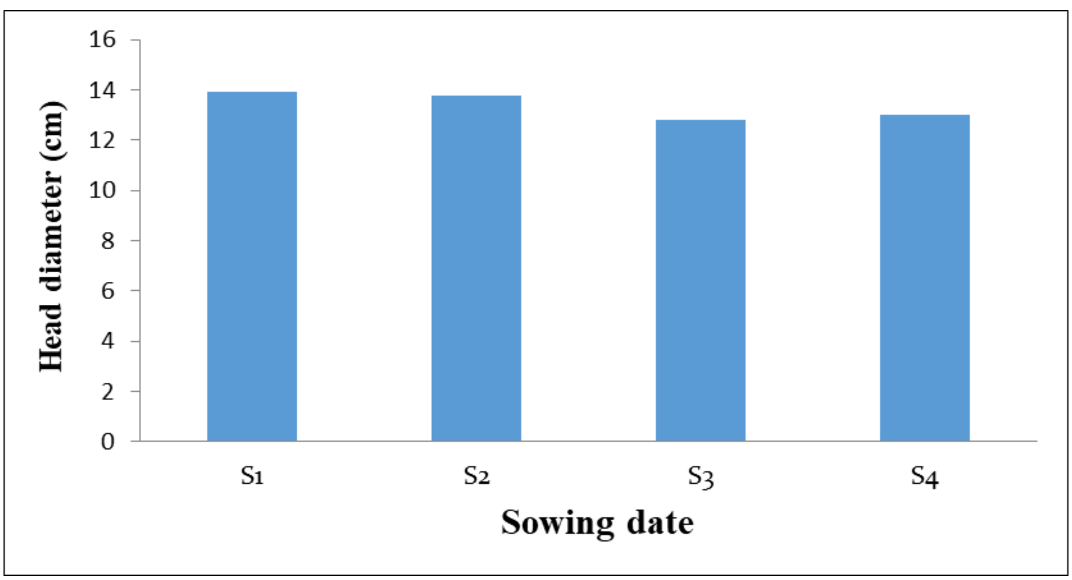
Sowing date of sunflower had the great influence on head diameter at harvest (Figure 11). It was observed that S_1 (21March) showed the highest head diameter (13.90 cm) which was not significantly different from S_2 (21 April). On the other hand, the lowest head diameter (12.83 cm) was recorded with S_3 (21 May) which was not significantly different from S_4 (22 May). This result is inconsistency with the findings of (Hilwa *et al.* 2019) who reported that head diameter increase in May and July Compare to March.

4.3.1.2 Effect of potassium

Head diameter was significantly influenced by potassium level (Figure 12). It was observed that at harvest K_1 (84 kg K ha^{-1}) recorded maximum head diameter (13.56 cm.) but not significantly different to K_2 .On the other hand, the lowest head diameter (13.08 cm.) was recorded with K_3. This indicate that potassium increase head diameter at a certain level then decrease. Similar trend was to found in mustard (lakhan *et al.* 2017). There was trend to decrease head diameter with increasing K.

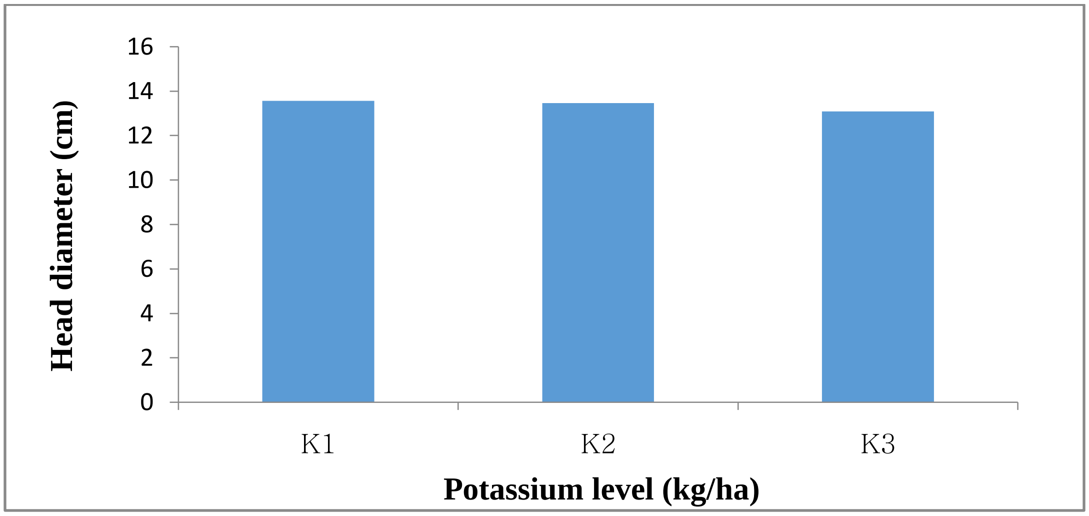
4.3.1.3 Combined effect of sowing date and potassium

The interaction effect of sowing date and potassium was significant effect on head diameter at harvest (Table 6). It was observed that the maximum head diameter was recorded with the treatment combination of S_1K_2 (14.90 cm) which was similar with S_2K_1. On the other hand, the lowest head diameter was recorded with the treatment combination of S_3K_3 (12.03cm), which was significantly similar with S_4K_2. The results obtained from all other treatment combinations were significantly different compared to highest and lowest results.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 11. Effect of sowing date on head diameter of sunflower (LSD $_{(0.05)}$ = 0.55).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 12. Effect of potassium level on head diameter of sunflower (LSD $_{(0.05)}$ = 0.38).

4.3.2 Number of seed head^{-1}

4.3.2.1 Effect of sowing date

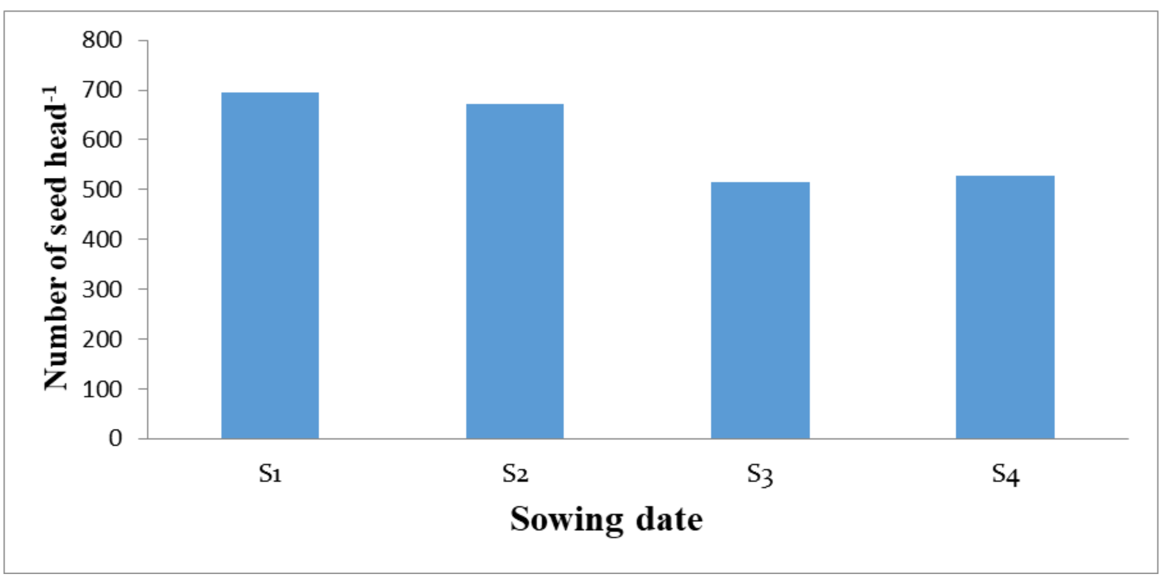
Sowing date of sunflower had the great significant influence on number of seeds plant^{-1} at harvest (Figure 13 and Appendix VIII). It was noticed that S_1 (21 March) showed the highest number of seeds plant^{-1} (693.6). On the other hand, the lowest number of seeds plant^{-1} (514.33) was recorded with S_3 (514.33) which was not significantly different from S_4.The intermediate result notice in S_2. Similar phenomenon was observed in soybean by Yagoub *et al.*, 2013 who found the significant differences for number of pod plant^{-1}, number of seeds pod^{-1} due to different sowing date.

4.3.2.2 Effect of potassium

Number of seeds $plant^{-1}$ was significantly influenced by different level of potassium (Figure 14 and Appendix VIII). It was observed that at harvest K_2 (105 kg K ha^{-1}) showed the maximum number of seeds $plant^{-1}$ (613.83) which was statistically similar with K_1 (21 March). On the other hand, the lowest number of seeds $plant^{-1}$ (588.25) was recorded with K_3 (126 kg K ha^{-1}). This result supported by Faisal *et al.*, 2013 who reported that increasing of potassium level significantly caused increasing in seed number, 1000 seed weight and yield decreased.

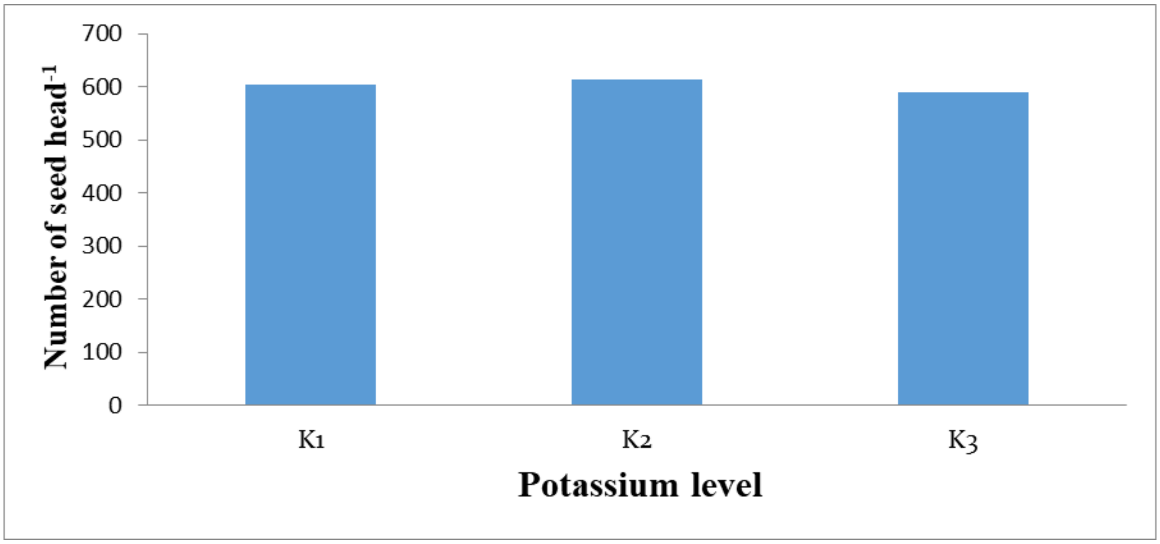
4.3.2.3 Combined effect of sowing date and potassium

The interaction effect of sowing date and potassium on the number of seeds $plant^{-1}$ was significant effect at harvest (Table 6 and Appendix VIII). It was observed that the maximum number of seeds $plant^{-1}$ was recorded with the treatment combination of S_1K_2 (717.67) which was not significantly different from S_1K_1 and S_2K_1. On the other hand, the lowest number of seeds $plant^{-1}$ (512.00) was recorded with the treatment combination of S_3K_3 which was significantly similar with S_4K_3, S_4K_1, S_3K_1 and S_3K_2 at harvest. The results obtained from all other treatment combinations were significantly different compared to highest and lowest results.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 13. Effect of sowing date on number of seeds head^{-1} of sunflower (LSD $_{(0.05)}$ = 18.94).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 14. Effect of potassium level on number of seeds head^{-1} of sunflower (LSD $_{(0.05)}$ =13.45).

4.3.3 Seed yield plant^{-1}

4.3.3.1 Effect of sowing date

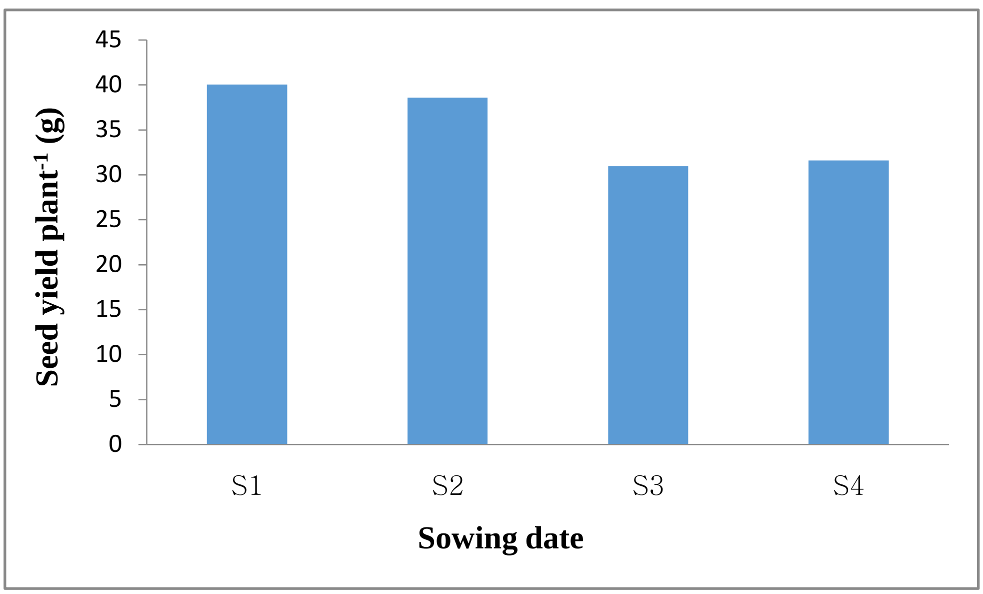
Sowing date of sunflower was the influence on seed yield plant-1 at harvest (Figure 15 and Appendix VIII). It was observed that S_1 (21 March) showed the highest seed yield plant^{-1} (40.03 g). On the other hand, the lowest seed yield plant^{-1} (30.97 g) was recorded with S_3 (22 May) which was not significantly different from S_4 (22 June).

4.3.3.2 Effect of potassium

Seed yield plant^{-1} was significantly influenced by level of potassium (Figure 16 and Appendix VIII). It was observed that at harvest K_2 (105 kg K ha^{-1}) showed the highest seed yield plant^{-1} (136.57 g). On the other hand, the lowest seed yield plant^{-1} (34.79 g) was recorded with K_3 (126 kg K ha^{-1}) which was identically similar with K_1 (84 kg K ha^{-1}). Similar phenomenon was observed in sesame by (Ahmad *et al.*, 2018).

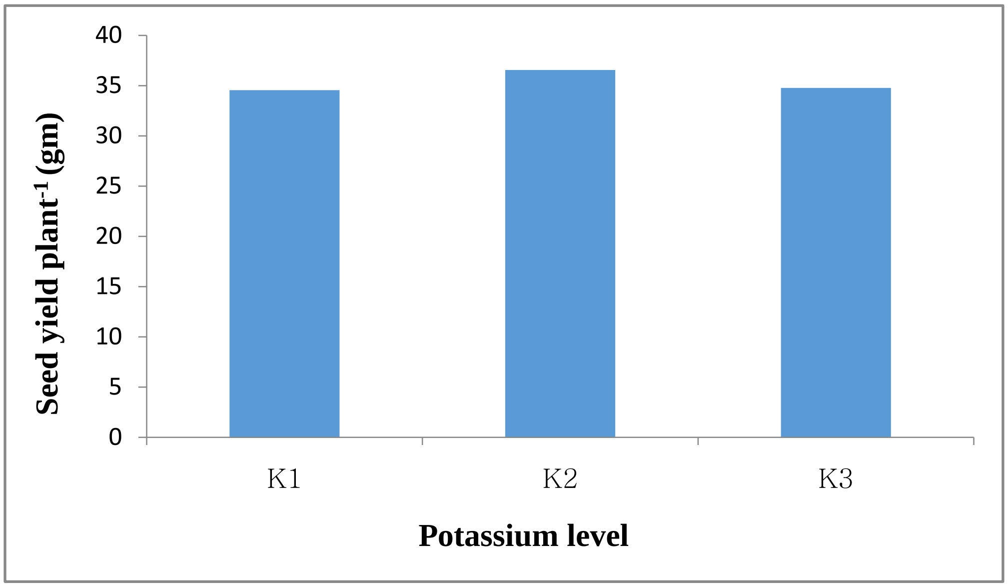
4.3.3.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on the seed yield plant^{-1} was significant effect at harvest (Table 6 and Appendix VIII). It was observed that the highest seeds plant^{-1} was recorded with the treatment combination of S_1K_2 (43.25g). On the other hand, the lowest number of seed plant^{-1} (30.31g) was recorded with the treatment combination of S_3K_3 which was significantly similar with S_4K_3, S_3K_1 and S_3K_2 at harvest. The results obtained from all other treatment combinations were significantly different compared to highest and lowest values.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 15. Effect of sowing date on seed yield plant^{-1} of sunflower (LSD $_{(0.05)}$ =1.02).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 16. Effect of different potassium levels on seed yield plant^{-1} of sunflower (LSD $_{(0.05)}$ =0.71).

4.3.4 Weight of 1000-seed

4.3.4.1 Effect of sowing date

Sowing date of sunflower was influence on 1000-seed weight at harvest (Figure 17 and Appendix VIII). It was observed that S_1 (21 March) showed the highest weight of 1000-seed (45.17g). On the other hand, the lowest weight of 1000-seed (40.78g) was recorded with S_4 (22 June) which was not significantly different from S_3 (22 May). Similar trend of 1000-seed weight in sunflower observed by (Demir, 2019) in respect to different sowing date.

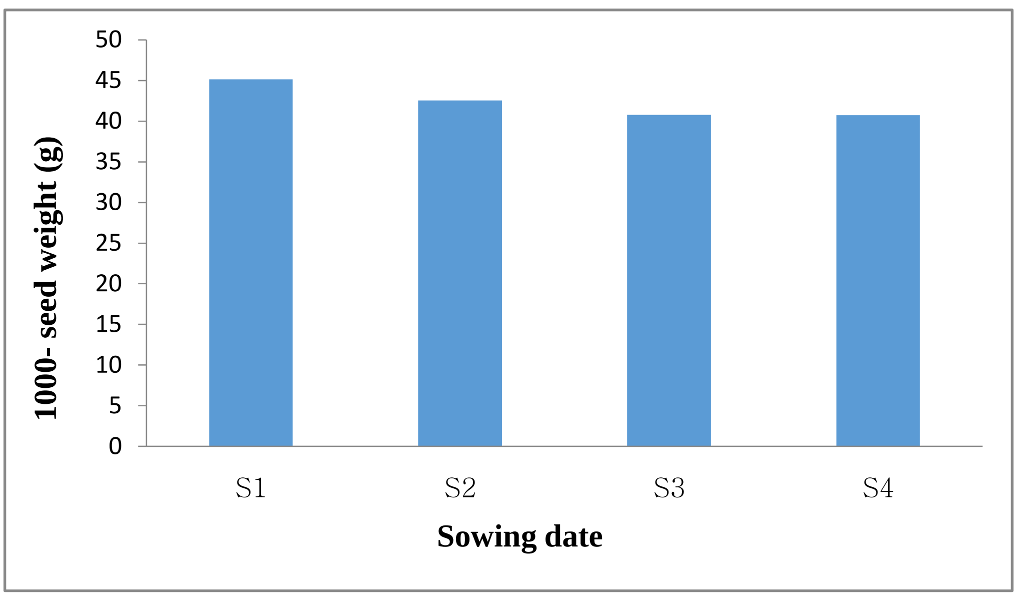
4.3.3.2 Effect of potassium

1000-Seed weight was significantly influenced by different level of potassium (Figure 18 and Appendix IX). It was observed that at harvest K_2 (105 kg K ha^{-1}) showed the highest

1000 - seed weight (43.00 g). On the other hand, the lowest (41.67 g) was recorded with K_3 (126 kg K ha^{-1}) which was identically similar with K_1 (84 kg K ha^{-1}). The result obtained from K_1 showed intermediate result. Shu-tian *et al*. (2018) reported that application of K also increased 1000-achene weight and kernel rate of both oil and edible sunflower.

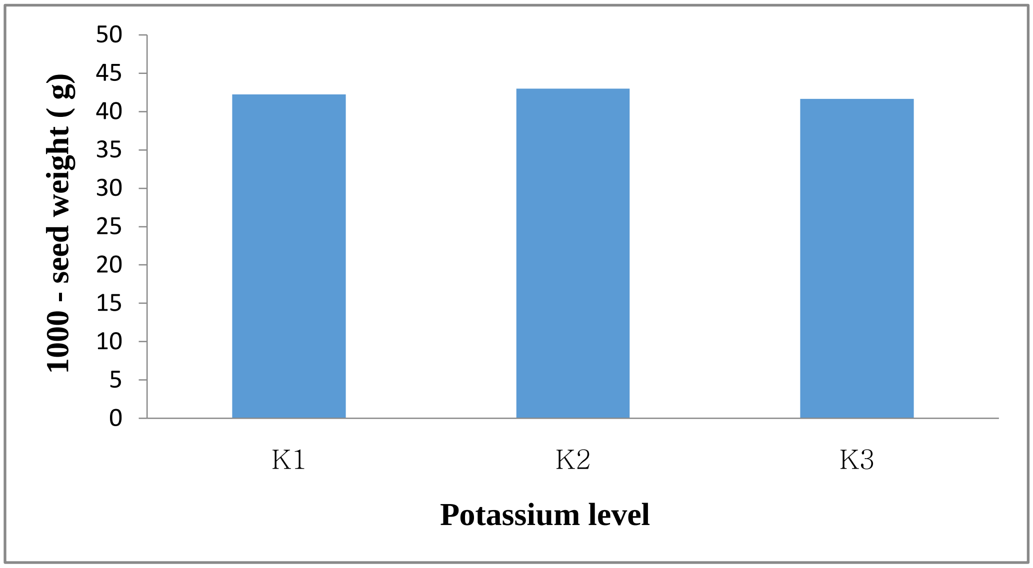
4.3.3.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on the weight of 1000-sees had significant effect at harvest (Table 6 and Appendix VIII). It was observed that the maximum 1000-seed weight (46.33 g) was recorded with the treatment combination of S_1K_2 which was statistically similar with S_1K_3. On the other hand, the lowest 1000-seed weight (39.00 g) was recorded with the treatment combination of S_3K_3 which was significantly similar with S_3K_3 at harvest. The results obtained from all other treatment combinations were significantly different compared to highest and lowest results



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 17. Effect of sowing date on 1000-seed weight of sunflower (LSD $_{(0.05)}$ =1.54).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 18. Effect of potassium level on 1000-seed weight of sunflower (LSD $_{(0.05)}$ =1.55).

Table 6. Combined effect of sowing date and potassium level on head diameter, number of seed head^{-1}, seed yield plant^{-1}, and weight of 1000-seed

Treatment Combination	Yield contributing characters			
	Head diameter (cm)	Number of seed head^{-1}	Seed yield plant^{-1} (g)	Weight of 1000-seed (g)
S_1K_1	13.13 c	671.67 b	35.03 d	43.17 bc
S_1K_2	14.90 a	717.67 a	43.25 a	46.33 a
S_1K_3	13.67 bc	691.67 ab	41.82 b	46.00 a
S_2K_1	14.17 ab	714.33 a	40.00 c	42.00 bcd
S_2K_2	13.60 bc	679.00 b	39.65 c	43.67 b
S_2K_3	13.47 bc	622.67 c	36.15 d	42.00 bcd
S_3K_1	13.34 bc	513.33 de	31.23 ef	41.33 cde

S_3K_2	13.10 c	517.67 de	31.39 ef	41.33 cde
S_3K_3	12.03 d	512.00 e	30.30 f	39.67 ef
S_4K_1	13.60 bc	516.00 de	31.93 e	42.50 bcd
S_4K_2	12.23 d	541.00 d	32.01 e	40.67 def
S_4K_3	13.16 c	526.67 de	30.89 ef	39.00 f
$LSD_{(0.05)}$	0.76	26.91	1.41	2.10
CV (%)	3.31	2.58	2.31	2.87

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 =22 June
K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K(105 kg K ha^{-1}); K_3 = 50% increase of recommended K(126 kg K ha^{-1})

4.4. Yield character

4.4.1 Seed yield ha^{-1}

4.4.1.1 Effect of sowing date

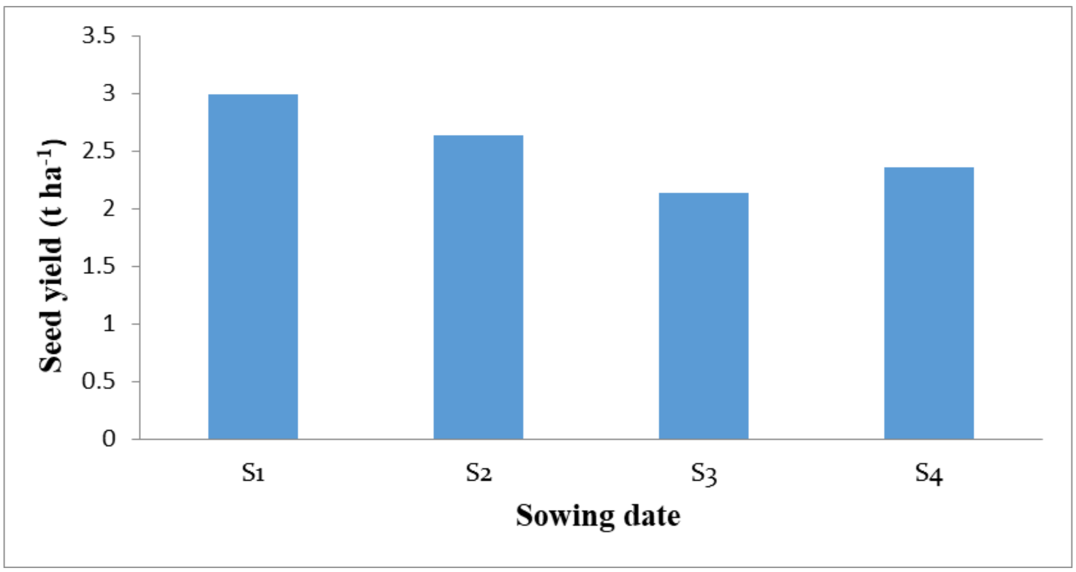
Sowing date of sunflower had the great influence on seed yield ha^{-1} at harvest (Figure 19 and Appendix IX). It was observed that S_1 (21 March) showed the maximum seed yield ha^{-1} (2.99 t) whereas minimum seed yield ha^{-1} (2.14 t) was recorded from S_3 (22 May). The intermediate result obtained from S_2 (21 April). Similar phenomenon was found in sunflower by Demir, 2019 who reported that when sowing date was delayed, seed and oil yields declined.

4.3.3.2 Effect of potassium

Seed yield ha^{-1} was significantly influenced by different level of potassium (Figure 20 and Appendix IX). It was observed that at harvest K_2 showed the highest seed yield ha^{-1} (2.63 t) while the lowest seed yield ha^{-1} (2.46 t) with K_3 which was identically similar with K_1. This result was supported by (Faisal *et al.*, 2013; Shu-tian *et al.*, 2018 and Mir *et al.*, 2010).

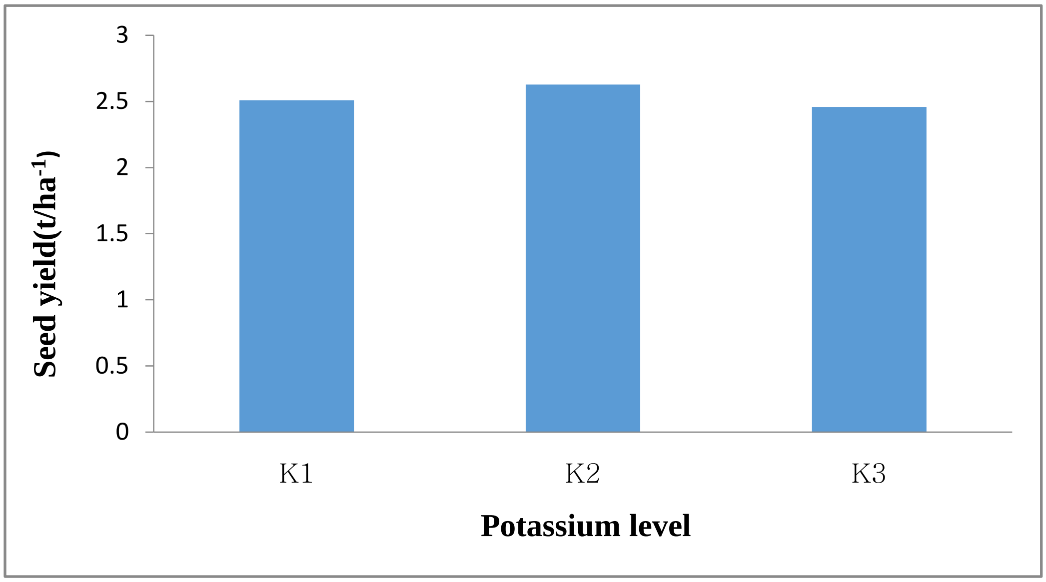
4.3.3.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on the seed yield ha^{-1} had significant effect at harvest (Table 7 and Appendix IX). It was found that the highest seed yield ha^{-1} (3.19 t) was recorded with the treatment combination of S_1K_2. On the other hand, the lowest seed yield ha^{-1} (2.08 t) was recorded with the treatment combination of S_3K_3 which was significantly similar with S_3K_1 at harvest. The results obtained from all other treatment combinations were significantly different from highest and lowest results.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 19. Effect of sowing date on seed yield ha^{-1} of sunflower (LSD $_{(0.05)}$ =0.13).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 20. Effect of potassium level on seed yield ha^{-1} of sunflower (LSD $_{(0.05)}$ = 0.09).

4.4.2 Stover yield ha^{-1}

4.4.2.1 Effect of sowing date

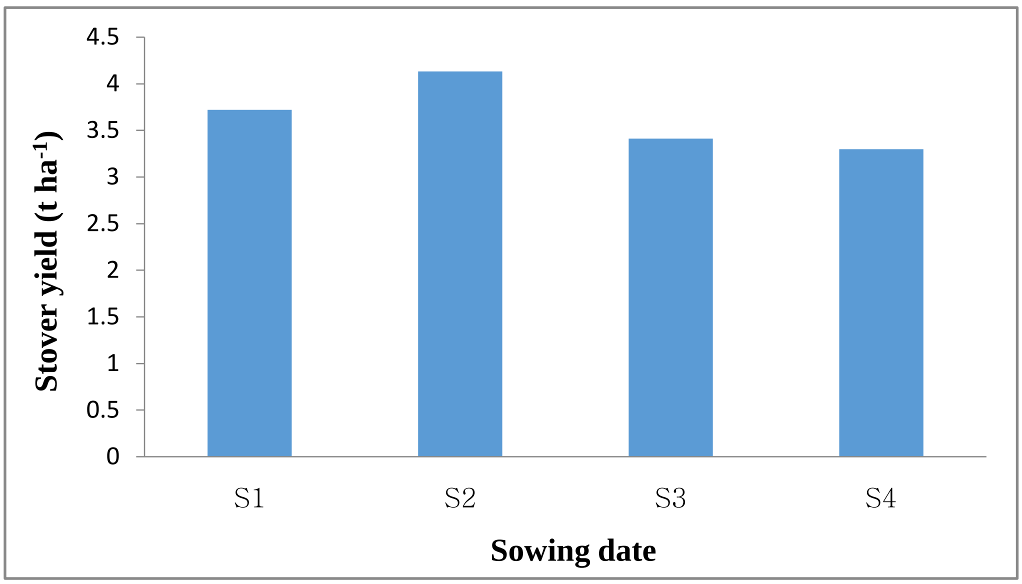
Sowing date of sunflower had the great influence on stover yield ha^{-1} at harvest (Figure 21). It was observed that S_2 (21 April) showed the maximum stover yield ha^{-1} (4.13 t) while the minimum seed yield ha^{-1} (3.30 t) was recorded with S_4 (22 June) which was not significantly different from S_3 (22 May). The intermediate result obtained from S_1. Oztark *et al.* (2017) observed similar phenomenon in sunflower.

4.4.2.2 Effect of potassium

Stover yield ha^{-1} was significantly influenced by different level of potassium (Figure 22). It was observed that at harvest K_1 (84 kg K ha^{-1}) showed the highest stover yield ha^{-1} (3.86 t). On the other hand, the lowest stover yield ha^{-1} (3.38 t) was recorded with K_3 (126 kg K). Similar result was found by Lakhan *et al.*, 2017 who reported that stover yields of mustard were significantly improved with the increase in the level of potassium.

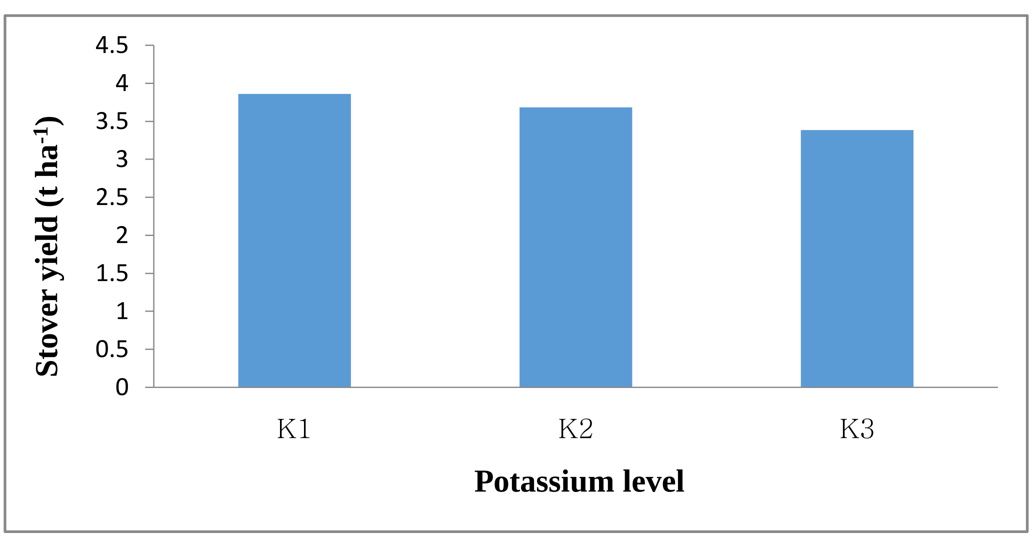
4.4.2.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium on the stover yield ha^{-1} had significant effect at harvest (Table 7). It was observed that the highest stover yield ha^{-1} (4.53 t) was recorded with the treatment combination of S_2K_2. On the other hand, the lowest stover yield ha^{-1} (3.10 t) was recorded with the treatment combination of S_3K_3 which was significantly similar with S_3K_2 and S_4K_3 at harvest. The results obtained from all other treatment combinations were significantly different from highest and lowest results



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 21. Effect of sowing date on stover yield ha^{-1} of sunflower (LSD $_{(0.05)}$ =0.20).



K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 22. Effect of potassium level on stover yield ha^{-1} of sunflower (LSD $_{(0.05)}$ =0.14).

4.4.3 Biological yield ha^{-1}

4.4.3.1 Effect of sowing date

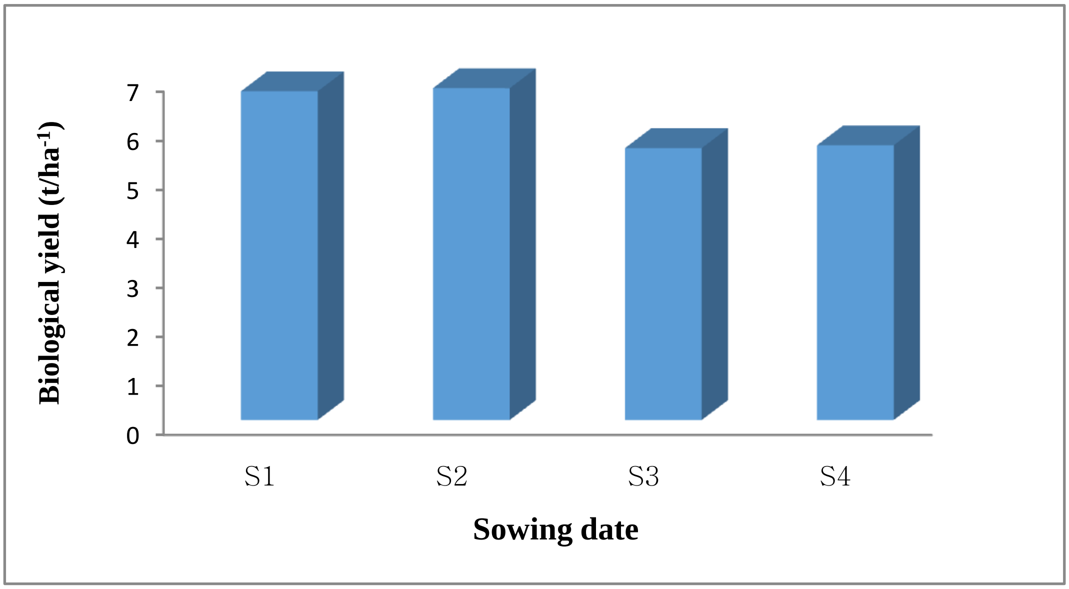
Sowing date of sunflower was significant influence on biological yield ha^{-1} at harvest (Figure 23). The maximum yield (6.77 t ha^{-1}) was recorded from S_2 (22 April) which was statistically similar with S_1 (21 March). The minimum biological yield (5.55 t ha^{-1}) was found from S_3 (22 May) which was not significantly different from S_4 (22 June).

4.4.3.2 Effect of potassium

Biological yield ha^{-1} varied significantly due to the application of different level of potassium (Figure 24). Maximum biological yield (6.36 t ha^{-1})) per plant was recorded in K_1 (84 kg K ha^{-1}) which was significantly similar with K_2 (105 kg K ha^{-1}) and lowest was recorded from K_1 (5.80 t ha^{-1}).

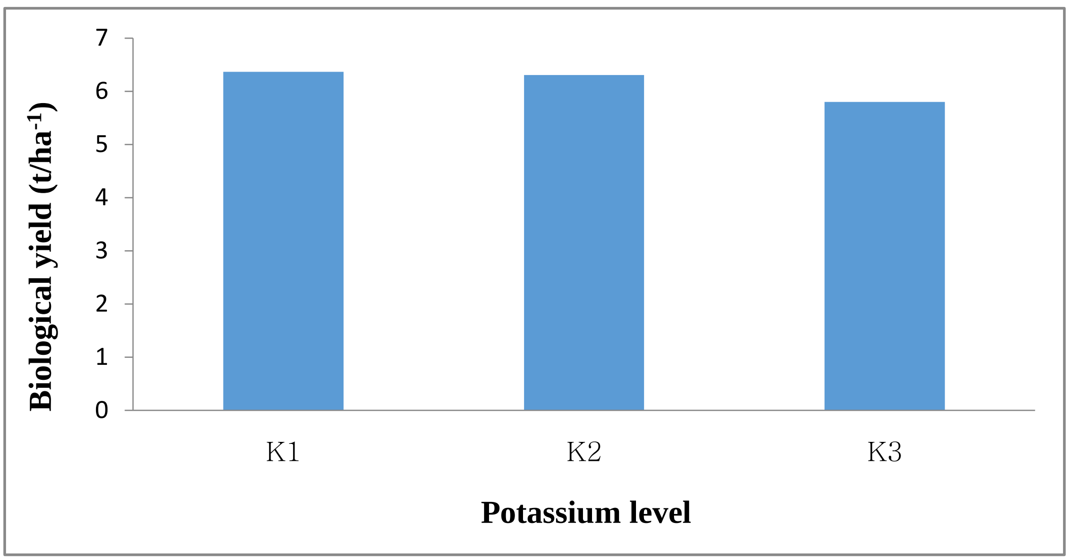
4.4.3.3 Interaction effect of sowing date and potassium

Significant variation was found due to the interaction effect of sowing date and potassium on biological yield ha^{-1} (Table 7). Biological yield ha^{-1} was recorded maximum in S_2K_2 (7.28 t ha^{-1}) which was significantly similar with S_1K_2. The lowest was recorded in S_3K_3 (5.19 t ha^{-1}) which was not statistically different from S_4K_2 and S_3K_2.



S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

Figure 23. Effect of sowing date on biological yield ha^{-1} of sunflower (LSD $_{(0.05)}$ =0.43).



K_1= Recommended K (84 kg K ha^{-1}); K_2= 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 24. Effect of potassium level on biological yield ha^{-1} of sunflower (LSD $_{(0.05)}$ =0.21).

4.4.4 Harvest index (%)

4.4.2.1 Effect of sowing date

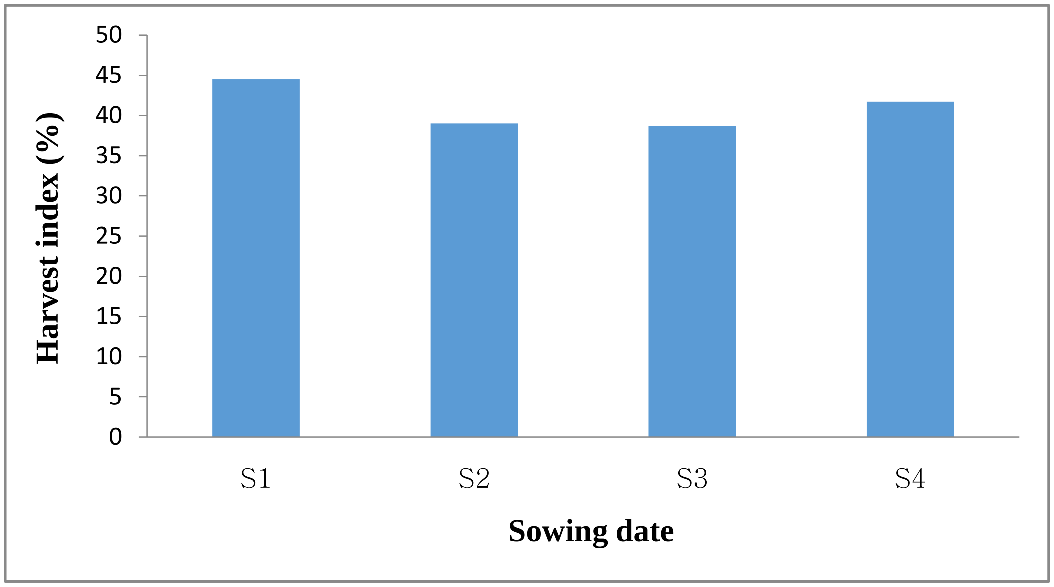
Sowing date of sunflower had the great influence on harvest index (Figure 25 and Appendix IX). It was observed that S_1 (21 March) showed the maximum harvest index (44.50%). On the other hand, the minimum (38.69%) was recorded with S_3 (22 May) which was not significantly different from S_2 (21 April). The intermediate result obtained from S_4 (22 June).

4.4.2.2 Effect of potassium

Harvest index was significantly influenced by different level of potassium (Figure 26 and Appendix IX). It was observed that at harvest K_3 (126 kg K ha^{-1}) showed the maximum harvest index (41.96%) which was not significantly different from K_2 (105 kg K ha^{-1}). On the other hand, the lowest harvest index (39.34%) was recorded with K_1 (84 kg K ha^{-1}).

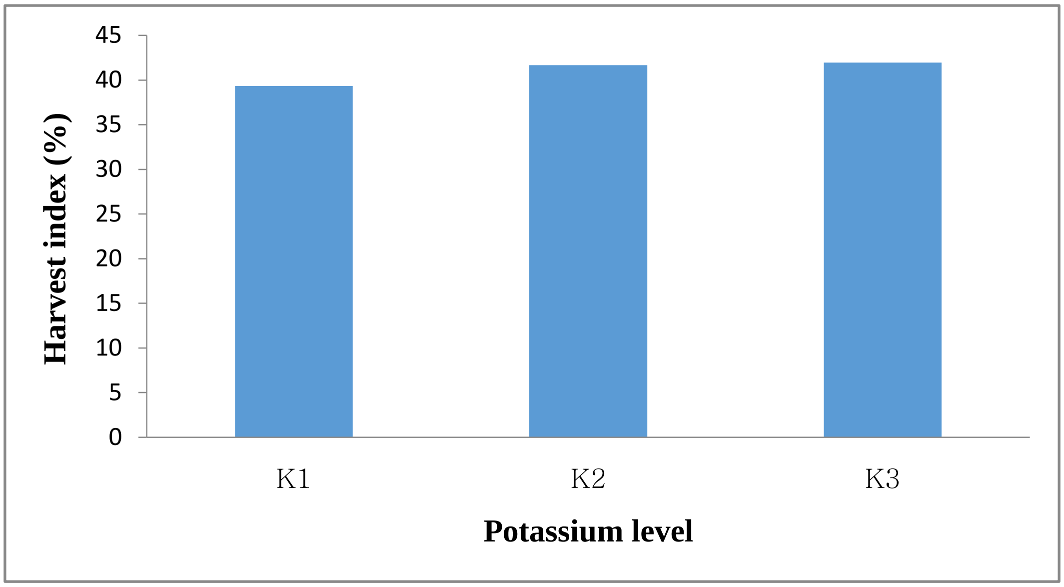
4.4.2.3 Combined effect of sowing date and potassium

The combined effect of sowing date and potassium had significant effect on harvest index at harvest (Table 7 and Appendix IX). It was observed that the maximum harvest index (45.88%) was recorded with the treatment combination of S_1K_2 which was significantly similar with S_1K_3. On the other hand, the lowest harvest index (35.09%) was recorded with the treatment combination of S_3K_1 which was significantly similar with S_2K_2 at harvest. The results obtained from all other treatment combinations were significantly different from highest and lowest results.



S_1 = 21 March, S_2 = 21April, S_3 = 22 May, S_4 = 22 June

Figure 25. Effect of sowing date on harvest index (%) of sunflower (LSD $_{(0.05)}$ =2.12).



K_1= Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K (105 kg K ha^{-1}); K_3 = 50% increase of recommended K (126 kg K ha^{-1})

Figure 26. Effect of potassium level on harvest index (%) of sunflower (LSD $_{(0.05)}$ =0.12).

Table 7. Combined effect of sowing date and potassium level on seed yield, stover yield, biological yield and harvest index

Treatments Combination	Yield characters			
	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
S_1K_1	2.78 c	3.86 bc	6.64 bc	41.80 bc
S_1K_2	3.19 a	3.76 cd	6.96 ab	45.88 a
S_1K_3	2.99 b	3.53 de	6.52 cd	45.83 a
S_2K_1	2.76 c	4.16 b	6.93 a-c	39.90 b-d
S_2K_2	2.75 c	4.53 a	7.28 a	37.76 de
S_2K_3	2.40 d	3.70 cd	6.10 de	39.34 cd
S_3K_1	2.12 f	3.93 bc	6.06 de	35.09 e
S_3K_2	2.20 ef	3.20 fg	5.40 fg	40.74 bc
S_3K_3	2.08 f	3.10 g	5.19 g	40.23 b-d
S_4K_1	2.36 de	3.46 d-f	5.83 ef	40.57 b-d
S_4K_2	2.36 de	3.23 e-g	5.59 e-g	42.23 b
S_4K_3	2.35 de	3.20 fg	5.39 g	42.41 b
$LSD_{(0.05)}$	0.18	0.28	0.41	2.40
CV (%)	4.11	4.48	3.85	3.38

(In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability)

S_1 = 21 March, S_2 = 21 April, S_3 = 22 May, S_4 = 22 June

K_1 = Recommended K (84 kg K ha^{-1}); K_2 = 25% increase of recommended K(105 kg K ha^{-1}); K_3 = 50% increase of recommended K(126 kg K ha^{-1})

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 (Tejgaon series under AEZ No.28) during Kharif-1 (March – September, 2019) to study the growth and yield performance of sunflower in response to sowing date and potassium level. The soil was silty clay loam in texture having pH 6.16 and organic carbon content of 0.68%. Two factor split-plot design was followed with 12 treatments combination having unit plot size of 2 m x 2 m and replicated thrice. Two factors (A) sowing date in main plot and (B) potassium level in sub–plot were initiated. Four sowing dates. (1). 21 March (S_1), (2). 21 April (S_2), (3). 22 May (S_3) and (4.) 22 June (S_4) and three potassium level viz: (1). Recommended potassium (84 kg K ha^{-1}) (K_1), (2). 25% increase of recommended potassium (105 kg K ha^{-1}) (K_2) and (3). 50% increase of recommended potassium (126 kg K ha^{-1}) (K_3) were comprised for the experiment. The treatment combinations were (i) S_1K_1 (21 March + 84 kg K ha^{-1}), (ii) S_1K_2 (21 March+ 105 kg K ha^{-1}), (iii) S_1K_3 (21 March+ 126 kg K ha^{-1}), (iv) S_2K_1 (21 April+ 84 kg K ha^{-1}), (v) S_2K_2 ((21 April + 105 kg K ha^{-1}), (vi) S_2K_3 (21 April+ 126 kg K ha^{-1}), (vii) S_3K_1 (22 May + 84 kg K ha^{-1}), (viii) S_3K_2 (22 May + 105 kg K ha^{-1}), (ix) S_3K_3 (22 May+ 126 kg K ha^{-1}) , (x) S_4K_1 (22 June + 84 kg K ha^{-1}), (xi) S_4K_2 ((22 June+ 105 kg K ha^{-1}), and (xii) S_3K_3(22 June + 126 kg K ha^{-1}). Sunflower seeds were sown on 21 March, 21 April, 22 May and 22 June respectively with S_1, S_2, S_3 and S_4, 2019 and the crop was harvested on 11 June, 12 July, 15 August and 13 September, 2019 respectively. The data were collected plot wise for plant height (cm), dry matter of stem ,leaves and reproductive organ , days to head initiation (80%) , days to maturity (80%) , head diameter (cm.), No. of seed $head^{-1}$,seed yield $plant^{-1}$ (g), 1000-seed weight (g), seed yield (t ha-1), stover yield (t ha-1) biological yield (t ha-1), and harvesting index etc. All the data were statistically analyzed following F-test and the mean comparison was made by Lsd. The results of the experiment are stated below.

Sowing date, potassium level and their interaction of sunflower according to the experiment had significant effect on plant height (cm), dry matter of stem ,leaves and reproductive organ , days to head initiation (80%) , days to maturity (80%) , head diameter (cm.), No. of seed plant^{-1} ,seed yield ha^{-1} (g), weight of 1000-seed (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}) , biological yield (t ha^{-1}),) and harvesting index etc .

Sowing 21 March showed highest plant height (141.60 cm) at 80 DAS, head diameter (13.90 cm.) at harvest, No. of seed plant^{-1} (693.6), seed yield head^{-1} (40.03 g), 1000-seed weight (45.17 g), seed yield (2.98 t ha^{-1}), and harvesting index 44.54%). The earliest maturity period also observed with this treatment; days to head initiation (80%) and days to maturity (80%) were 35 and 74 days. But in case of dry weight of stem (23.64 g), leaf (22.04 g), reproductive organ (head) (18.83g), stover yield (4.13 t ha^{-1}) and biological yield (6.77 t ha-1) was found from sowing 21 April.

The lowest dry weight of stem (17.60 g), leaf (16.27 g), reproductive organ (head) (13.95 g), head diameter (12.83 cm.), No. of seed plant^{-1} (514), seed yield plant^{-1} (30.97 g), seed yield ha^{-1} (2.14 t ha^{-1}), biological yield (5.55 t ha^{-1}), harvesting index (38.69%) was obtained by sowing 22 May. But in case of plant height (118.72 cm) at 80 DAS, 1000 - seed weight (40.78 g), stover yield (3.30 t ha^{-1}) obtained from 22 June. The delayed maturity period also observed with this treatment; days to head initiation (80%) and days to maturity (80%) were 39 and 77 days.

The factor affecting different potassium level where highest plant height (131.43 cm) at 80 DAS, dry matter of stem(21.01 g), reproductive organ (head) (16.55 g), No. of seeds head^{-1} (613.83), seed yield ha^{-1} (36.57 g), weight of 1000-seed (43.00 g), seed yield (2.63 t ha^{-1}) obtained from K_2 (105 kg K ha^{-1}). The shorten maturity period also observed with this treatment; days to head initiation (80%) and days to maturity (80%) were 37 and 74 days. But head diameter (13.56 cm.), biological yield (6.36 t ha^{-1}), stover yield (3.58 t ha^{-1}) was found with K_1 (84 kg K ha^{-1}) and harvesting index (41.54%) and dry weight of leaf (19.71 g) with K_3 (126 kg K ha^{-1}).

The lowest dry weight reproductive organ (head) (16.19g), head diameter (13.08cm.), No. of seed head^{-1} (588.25), seed yield plant^{-1} (34.792g), weight of 1000-seed (41.667g), seed yield (2.45 t ha^{-1}), stover yield (5.38 t ha^{-1}) was found with K_3 (126 kg K ha^{-1}). The longest maturity period also observed with this treatment; days to head initiation (80%) and days to maturity (80%) were 38 and 76 days. But plant height (127.82 cm) at 80

DAS, dry matter of stem (18.89 g), leaf (18.42 g), biological yield (t ha^{-1}), and harvesting index (39.34%) noticed in K_1 (105 kg K ha^{-1})

The highest plant height (142.67 cm), head diameter (14.90 cm.) No. of seed $plant^{-1}$ (717.67), seed yield $plant^{-1}$ (43.25 g), weight of 1000-seed (46.33 g), seed yield (3.19 t ha^{-1}), and harvesting index (45.88%) were obtained with the combined effect of S_1K_2 (21 March+105 kg K ha^{-1}). But dry weight of stem (24.93 g) and reproductive organ (19.54 g), biological yield (7.28 t ha^{-1}), stover yield (4.53 t ha^{-1}) was recorded with S_2K_2 (21 April + 105 kg K ha^{-1}). The shortest maturity period also observed with this treatment; days to head initiation (80%) and days to maturity (80%) were 34 and 78 days. But dry matter of leaves (22.33 g) was obtained from S_2K_3 (21 April+126 kg K ha^{-1}).

The lowest dry matter of stem (24.20 g) , head diameter (12.03 cm.), No. of seed $plant^{-1}$ (512) ,seed yield $plant^{-1}$ (30.30 g), weight of 1000-seed (39.00 g), seed yield (2.08 t ha^{-1}), stover yield (3.10 t ha^{-1} , biological yield (7.283 t ha^{-1}) were observed with the treatment combination of S_3K_3(22 June +126 kg K ha^{-1}).The longest maturity period also observed with this treatment combination; days to head initiation (80%) and days to maturity (80%) were 40 and 77 days. But lowest plant height (115 cm) at 80 DAS with S_4K_1 (22 June + 84 kg K ha^{-1}), dry weight of reproductive organ (head) (13.50 g) with S_3K_2 (22May + 105 kg K ha^{-1}), leaf (14.93 g) and harvesting index (35.09%) with S_3K_1 (22 May + 84 kg K ha^{-1}).

Considering all the parameters studied the following conclusion may be drawn-

- The suitable sowing date on growth and yield performance of sunflower was observed on 21 March (kharif-I season).
- The effective potassium level on growth and yield performance of sunflower was observed with 105 kg K ha^{-1}.
- The suitable interaction effect on growth and yield performance of sunflower was observed from 21 March with 105 kg k ha^{-1}.

Based on the results of the present study, the following recommendation may be drawn-

- The combined effect of sowing date (21 March) and k level (105 kg K ha^{-1}) may be suitable in Tejgaon series under AEZ No. 28 to obtain higher yield and yield performance of sunflower.

However, to reach a specific conclusion and recommendation, more research work on sunflower should be done in different Agro-ecological zones of Bangladesh.

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APPENDICES

Appendix I. Characteristics of the experimental field

A. Morphological characteristics of the experimental field

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

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

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

Source: SRDI

Appendix II. Monthly meteorological information during the period from February, 2019 to September, 2019

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	March	35.20	21.00	52.44	20.4
	April	34	24	54	225.1
	May	37	28	61	259.3
	June	39	29	67	273.6
	July	32.6	26.8	81	373.1
	August	32	25	80	316.5
	September	32.4°	25.7	83	300.4

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

Appendix III. Analysis of variance of the data on plant height at different days after sowing (DAS) as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square of plant height at			
		20DAS	40DAS	60DAS	80DAS
Replication (A)	2	0.083	3.03	1.863	3.12
Sowing date (B)	3	309.150**	5813.89**	837.518**	1308.56**
Error I	6	0.194	2.97	2.197	7.35
Potassium level (C)	2	5.644**	36.58**	7.665*	46.44**
B×C	6	0.802**	12.47*	13.910**	20.07*
Error II	16	0.167	3.54	2.113	6.85
Total	35				

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix IV. Analysis of variance of the data on stem dry matter weight at different days after sowing (DAS)) as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square			
		20DAS	40DAS	60DAS	80DAS
Replication (A)	2	0.00115	0.09750	0.0975	0.1158
Sowing date (B)	3	0.13883**	1.16956*	53.5958**	70.6477**
Error I	6	0.00060	0.13750	0.1375	0.2603
Potassium level (C)	2	0.02323**	3.13439**	2.1733**	13.6744**
B×C	6	0.01370**	0.56094**	2.7600**	4.5052**
Error II	16	0.00074	0.12750	0.1275	0.2242
Total	35				

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix V. Analysis of variance of the data on leaf dry matter weight at different days after sowing (DAS)) as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square			
		20DAS	40DAS	60DAS	80DAS
Replication (A)	2	0.00250	0.0678	0.0658	0.6100
Sowing date (B)	3	1.37675**	37.9369**	42.2488**	55.2292**
Error I	6	0.00472	0.0900	0.1436	0.4352
Potassium level (C)	2	2.89108**	4.4903**	24.5972**	6.3169**
B×C	6	0.11454**	0.4956**	1.5261**	0.6603**
Error II	16	0.00417	0.0844	0.1242	0.1539
Total	35				

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VI. Analysis of variance of the data on dry matter weight of reproductive parts (head) at different days after sowing (DAS)) as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square		
		40DAS	60DAS	80DAS
Replication (A)	2	0.00083	0.11583	0.1633
Sowing date (B)	3	0.05287**	8.39185**	43.5781**
Error I	6	0.00194	0.26028	0.1263
Potassium level (C)	2	0.05354**	3.63000**	0.3957*
B×C	6	0.01321**	1.18074**	4.5238**
Error II	16	0.00167	0.22417	0.0656
Total	35			

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VII. Analysis of variance of the data on days to head initiation and days to maturity as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square of days to	
		Head initiation	Maturity
Replication (A)	2	0.2500	0.3333
Sowing date (B)	3	21.6296**	17.2963**
Error I	6	0.4722	0.7778
Potassium level (C)	2	6.0278**	5.3333**
B×C	6	2.1019**	2.0741*
Error II	16	0.4167	0.6667
Total	35		

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VIII. Analysis of variance of the data on head diameter, number of seeds head^{-1}, seed yield plant^{-1} and 1000-seed weight as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square			
		Head diameter	Number of seeds head^{-1}	Seed yield plant^{-1}	1000-seed weight
Replication (A)	2	0.09880	158.3	0.333	0.5119
Sowing date (B)	3	2.57558**	79442.0**	196.951**	39.2685**
Error I	6	0.22769	269.4	0.778	1.8008
Potassium level (C)	2	0.76410*	1994.7**	14.712**	5.3611*
B×C	6	1.68328**	2170.7**	19.626**	6.1574*
Error II	16	0.19547	241.7	0.667	1.4786
Total	35				

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix IX. Analysis of variance of the data on seed yield ha^{-1}, stover yield ha^{-1}, biological yield ha^{-1} and harvest index as influenced by sowing date, potassium level and their interaction

Source	Df	Mean square			
		Seed yield ha^{-1}	Stover yield ha^{-1}	Biological yield ha^{-1}	Harvest index
Replication (A)	2	0.00583	0.01333	0.08364	3.5833
Sowing date (B)	3	1.20714**	1.25435**	4.06706**	66.4725**
Error I	6	0.01250	0.03111	0.13698	3.3611
Potassium level (C)	2	0.08945**	0.69250**	1.17105**	24.5312**
B×C	6	0.05979**	0.20102**	0.28662**	9.3484**
Error II	16	0.01083	0.02667	0.05613	1.9167
Total	35				

*Significant at 5% level of probability
** Significant at 1% level of probability