GROWTH AND YIELD OF MUSTARD (*Brassica Campestris*) AS INFLUENCED BY DIFFERENT LEVELS OF POTASSIUM AND ZINC

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CERTIFICATE

This is to certify that thesis entitled, "**GROWTH AND YIELD OF MUSTARD AS INFLUENCED BY DIFFERENT LEVELS OF POTASSIUM AND ZINC (*BRASSICA CAMPESTRIS*)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the result of a piece of Bonafede research work carried out by **MD. RAJU MIR, REGISTRATION NO. 19-10358** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

....

Dated: **(Prof. Mst. Afrose Jahan)**

Place: Dhaka, Bangladesh **Supervisor**

DEDICATED
TO

MY

BELOVED
PARENTS

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
N	=	Nitrogen
B	=	Boron
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Murate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

ABSTRACT

The experiment was undertaken at the field of Sher-e-Bangla Agricultural University, during rabi season (October to March) of 2020-21 to growth and yield of mustard as influenced by different levels of potassium and zinc (*brassica campestris*). In this experiment, the treatment consisted of three different K levels viz. K_0 = 0 kg ha^{-1}, K_1 = 55 kg ha^{-1} and K_2 = 65 kg ha^{-1} and three different level of Zn viz. Zn_0 = 0 kg ha^{-1}, Zn_1 = 1.5 kg ha^{-1} and Zn_2 =2.5 kg ha^{-1}. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There are 9 treatment combinations of different level of potassium and Zinc. The seeds were sown at the rate of 7 kg ha^{-1}. The highest plant height, number of leaves per plant, number of branches per plant, length of siliquae, number of siliquae per plant, number of seed per siliquae, thousand seed weight, yield of seed per hectare (1.63 t) was obtained from 65 kg ha^{-1} K. The highest plant height, number of siliquae per plant, thousand seed weight, seed yield (1.45 t) was recorded along with 2.5 kg ha^{-1} Zn. The interaction between different levels of K and Zn was significantly influenced on almost all morphological parameters and yield contributing characters including seed yield. The maximum value of morphological parameters, yield contributing characters and seed yield of mustard were observed with treatment T_9 (the combined dose of 65 kg ha^{-1} K along with 2.5 Kg ha^{-1} Zn) whereas the lowest values were obtained from treatment 1 (control condition, 0 kg/ha K and 0 kg ha^{-1} Zn treatment combination). The maximum yield of seed per hectare (1.67 t) was obtained from T_9 (65 kg ha^{-1} K with 2.5 Kg ha^{-1} Zn treatment combination). The highest Stover yield and biological yield was recorded from T_9 (65 kg ha^{-1} K with 2.5 kg ha^{-1} Zn). T_8 (combination of 65 kg ha^{-1} K with 1.5 Kg ha^{-1} Zn) gives almost similar result with T_9.

CHAPTER I

INTRODUCTION

The mustard plant belongs to the Cruciferae (Brassicaceae) family. Mustard used in food is often a mixture of seeds from two or more species of Brassicaceae, for example, Sinapis alba L. (white or yellow mustard), *Brassica nigra* (black mustard) and *Brassica juncea L*. (Brown or oriental mustard). Mustards are functional foods having beneficial physiological effects in humans. Sinapis alba can be used as a source for a wide range of active components including isothiocyanates, phenolics, dithiolthiones and dietary fiber. Flour from the yellow species (*Sinapis alba*) is used most commonly in Europe, while oriental mustard (*Brassica juncea*) is used most commonly in the United States and Japan. Mustard consumption in different countries varies according to local food habits. Mustard is principally grown as a source of condiment for the spice trade. Sinapis alba is commonly known as "white" or "yellow" mustard and contributes a "hot" principle which results in a sensation of sweetness and warmth. Brassica juncea, commonly called "brown" or "oriental" mustard, contributes the "pungent" principle. Mustard plant at different types have been widely cultivated and used as spice, medicine and a source of edible oil since ancient times. The mustard seed is rich in protein. The protein is of excellent nutritional quality, being rich in lysine with adequate amounts of sulfur containing amino acids-limiting amino acids in most of the cereals and oilseed proteins. The use of protein rich full-fat or defatted flour shows promise in improving the nutritive value of the final product as well as optimum utilization of the flour. Protein fortification of food is of current interest because of increasing consumer's awareness towards health and quality of food. Mustard is used on some meat products, such as hotdog and burger.but is very often an added ingredient in sauces, salads and other foods; for example, mayonnaise, salad dressing, barbecue and related products as well as ketchup, may contain mustard. Mustard is also used in various traditional remedies to stimulate appetite and as a laxative, expectorant and antiseptic agent for the treatment of various gastrointestinal, respiratory and skin diseases. The mustard plant, mainly the seeds, contain special compounds namely glucosinolates. These compounds characterize this flavour of mustard and mustard products. In Bangladesh, oil seed mustard is the number one edible oil crop, covering about 80% of the total oil crops area and contributing to more than 71% of the total oil crop production (BBS, 2019). And beside our country in India whereas mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis Jacq*.) oil. Among the seven edible oilseed cultivated in India, mustard (*Brassica spp*.) contributes 28.6% in the total production of oilseeds. In India, it is the second most important edible oilseed after groundnut sharing 27.8% in the India's oilseed economy. The share of oilseeds is 14.1% out of the total cropped area in India, mustard accounts for 3% of it. The global production of mustard and its oil is around 38–42 and 12–14 mt, respectively. India contributes 28.3% and 19.8% in world acreage and production. India produces around 6.7 mt of mustard next to China (11-12 mt) and EU (10–13 mt) with significant contribution in world mustard industry. Bangladesh is facing a huge deficit of edible oil. In view of the importance of this crop, attention has to be given to increase its production in order to meet the huge shortage of cooking oil in the country. According to the National Nutrition Council (NNC) of Bangladesh the recommended dietary allowance (RDA) is estimated to be 6gm oil capita/day for a diet with 2700 Kcal (NNC, 1984). On this RDA basis, Bangladesh requires 0.29 million tons of oil equivalent to 0.8 million tons of oil seeds for nourishing her people. The soils of Bangladesh have recently been found to be deficient in secondary macro nutrient elements due to the use of non-judicious chemical fertilizers, such as Urea, TSP, MP, higher cropping intensity, without proper replenishment of nutrients. For this reason, Mg, S, B and Zn deficiencies are being observed in many parts of the country (Islam and hossain, 1993). Potassium (K) aids in water uptake and starch production. Adequate levels are required for disease, drought, and frost tolerance. As with N, a major symptom of K deficiency is the yellowing of the leaf margins. Potassium-deficient plants will have reduced growth, smaller leaves, and thinner stands. Potassium is the third key nutrient of commercial fertilizers. It helps strengthen plants' abilities to resist disease and plays an important role in increasing crop yields and overall quality. Potassium (K) is the most abundant inorganic cation, and it is important for ensuring optimal plant growth (White and Karley, 2010). K is an activator of dozens of essential enzymes, such as protein synthesis, sugar transport, N and C metabolism, and photosynthesis. Jun 2, 2020. also protects the plant when the weather is cold or dry, strengthening its root system and preventing wilt. On the other hand, Zinc is an essential component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not in plant tissue. Carbohydrate, protein and chlorophyll formation is significantly reduced in zinc-deficient plants. It was found that the application of varying doses of zinc sulfate as soil application had a significant effect on the seed yield of mustard over control in all five years. It increased the average seed yield from 13.3 to 17.5 q/ha which accounted for a 32 percent increase over control. Mustard is cultivated in mostly under temperate climates. It is also grown in certain tropical and subtropical regions as a cold weather crop. Bangladeshi mustard is reported to tolerate annual precipitation of 500 to 4200 mm, annual temperature of 6 to 27°C, and pH of 4.3 to 8.3. Mustard follows C3 pathway for carbon assimilation. Therefore, it has efficient photosynthetic response at 15–20°C temperature. At this temperature the plant achieve maximum CO2 exchange range which declines thereafter. Rai is mostly grown as a rainfed crop, moderately tolerant to soil acidity, preferring a pH from 5.5 to 6.8, thrives in areas with hot days and cool night and can fairly sustain drought. Mustard requires well-drained sandy loam soil. Mustard has a low water requirement (240–400 mm) which fits well in the rainfed cropping systems. Nearly 20% area under these crops is rainfed. A review is prepared on advances on agronomic practices for enhancing the mustard production in India. A review of the work done on the different aspects in India and abroad especially under advance agronomic practices is done in this paper. The present study shows the effects of treatment to the seeds *Brassica juncea* L. variety BARI Sharisha 15 with potassium (KCl) and zinc ($ZnSO_4$) in varying concentration. And it is likely that the effects of potassium and zinc is very sensitive to oilseed crops basically in mustard. On the other hand a maintained population plays a significant role in producing higher yield. In addition, the fertilizer requirement with different population densities for maximum growth and yield of newly developed mustard variety BARI Sharisha 15 is not much investigated. With a view to determining the effect of K and Zn on growth and yield of this new variety, a field study was conducted with the following objectives-

1. To determine the suitable dose of potassium and zinc for the growth and yield of mustard.

2.To study the effect of potassium and zinc levels on growth, yield and quality of mustard.

3.To study the interaction effect of potassium and zinc levels on growth, yield and quality of mustard

CHAPTER II

REVIEW OF LITERATURE

2.1: Effect of Potassium on Mustard

Field experiments were conducted at Dry land research farm, Bichpuri, Agra for three consecutive years to find out the response of mustard to potassium application against RDF in terms of seed yield. In Agra, farmers, in general, apply recommended dose of N and P fertilizers omitting potassium (K) from their fertilization schedule. This lack of K may be responsible for low yields and poor crop quality apart from other major physiological and biochemical requirements in plant growth. Seed yield and productivity of mustard still can be further improved in Agra by use of balanced fertilization. Application of 40 and 60 kg k/ha along with RDF increased the seed yield of mustard by 22.77 and 23.15% respectively over RDF (Only N and P were applied). Seed yield obtained with 40 and 60 kg K/ha were statistically at par during all three years, implying the application of 40 kg K/ha along with 100% RDF was good enough to meet the K requirement of mustard grown on low to medium status soils of Agra distric.

On-farm trials were conducted for two consecutive years to find out the response of mustard to potassiumapplication against state recommended dose of nitrogen (N) and phosphorus (P) fertilisers in terms of yield gains and nutrient accumulation. Application of 20 kg potassium (K) 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 N_{80} P_{30} alone (SRDF). Seed yields 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. Like mustard seed yield, the uptake of macronutrients [N, P, K and Sulphur (S)] and micronutrients [Zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe)] were lowest in N_{80} P_{30} treatment (SRDF) and significant increase in uptake of these nutrients was observed where application of potassium was made along with SRDF. The mean N, P, K and S uptake by mustard under SRDF + K_{20} 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 + K_{20} treatment.

A field experiment was carried out 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 K2O ha^{-1}) were evaluated in randomizrd block design with four replications. The results revealed that the plant height, yield attributes (siliqu/plant, seeds/silqua 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 (19.50q ha^{-1}) and stover yields (57.77q ha^{-1}) were recorded with 60 kg K_2O ha^{-1}. Application of kg 60 K_2O ha^{-1} resulted in 30.5% higher grain and 33.1 % stover yield than the yield obtained in the control (14.9 and 43.38-1). 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 maximum values of protein content (20.4 %) and oil content (39.3 %) were recorded with 80 and 60 kg K_2O ha^{-1} respectively. The uptake values of N, P, K and S by seed and stover increased significantly with potassium up to 60 kg K_2O ha^{-1}. Available potassium in post-harvest soil improved significantly with K levels and maximum value of 166.0 kg ha was recorded with 80 kg K_2O ha^{-1} .

A field experiment was conducted at Agronomy Farm, College of Agriculture, Nagpur during rabi season 2020-21 to study the effect of potassium and sulphur on growth yield and economics of mustard under irrigated condition. The experiment was laid out in factorial randomized block design (FRBD) with 12 treatments and three replications. The treatments comprised of four potassium levels (30, 35, 40, 45 kg ha^{-1}) and three sulphur levels (15, 20, 25 kg ha^{-1}) to mustard. The growth and yield attributes viz. plant height, number of branches $plant^{-1}$, dry matter accumulation $plant^{-1}$, number of siliqua $plant^{-1}$ and seed yield $plant^{-1}$ were significantly maximum with application of potassium @ 45 kg ha^{-1} as compared to application of potassium @ 35 kg ha^{-1} and 30 kg ha^{-1} but was found at par with the application of potassium @ 40 kg ha^{-1} . These growth and yield attributes were also found significantly higher with application of sulphur @ 25 kg ha^{-1} as compared to application of sulphur @ 15 kg ha^{-1} but was found at par with application of sulphur @ 20 kg S ha^{-1} of mustard. Significantly higher seed yield (855 kg ha^{-1}) and stover yield (3368 kg ha^{-1}) were recorded with application of potassium @ 45 kg ha^{-1} which was found at par with 40 kg ha^{-1} potassium application to mustard. In case of sulphur application, significantly higher seed yield (798 kg ha^{-1}) and stover yield (3210 kg ha^{-1}) was recorded with application of 25 kg sulphur ha^{-1}, which was found at par with application of 20 kg S ha^{-1} to mustard. Relative economic analysis of mustard crop indicated that the maximum gross monetary returns (Rs.43105 ha^{-1}), net monetary returns (Rs.27060 ha^{-1}) were recorded with application of potassium @ 45 kg ha^{-1} as compared to application of potassium @ 35 kg ha^{-1} and 30 kg ha^{-1} but was found at par with application of 40 kg K ha^{-1} to mustard. Application of sulphur @ 25 kg ha^{-1} gave significantly higher gross monetary returns (Rs .40319 ha^{-1}), net monetary returns (Rs. 24504 ha^{-1}) which was found at par with application of 20 kg S ha^{-1} to mustard.

Mustard is an important oil seed crop and plays vital role in boosting the country economy especially in Pakistan. Unfortunately, under the sudden fluctuation in the climatic conditions, water stress is one of the most drastic factors restricting its production. To mitigate the water scarcity impact, soil applied potash has emerged as a sustainable approach in improving the crop oil production. For this purpose, two years filed trials were conducted at the Agronomic field research-area, Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan during two consecutive growing seasons 2017-18 and 2018-19. The Randomized Complete Block Design was used with two factorial arrangements having three replications. Different factors were Fa; irrigation water stress i.e. (no stress (control)), stress at vegetative stage (Sveg), stress at vegetative & reproductive stages (Sveg+rep)) and Fb; potash application i.e. (0, 30, 60 and 90 kg ha-1) at the time of sowing. Mustard hybrid (45S42) was used as a test specie. Observations shown that water stress at Sveg resulted in grain yield reduction (47%) as compared to control. In the case of potash fertilizer treatments particularly at 60 kg ha-1 was significantly alleviated the detrimental effect (15% in yield-related components) of water stress both in Sveg and Sveg+rep conditions as per control. Nevertheless, potash application at 60 kg ha-1 depicted increase of oil-contents (35%) as per with other treatments under the applied irrigation water stress at Sveg and Sveg+rep conditions during the both years of trials. Based on the results of economic analysis, potash application at 60 kg ha-1 is an easy, efficient, commercially feasible and cost-effective agronomic approach for compensating the adverse effects of water stress in mustard crop.

Potassium Most of the higher plants require potassium in large quantity (1 per cent on dry weight basis) for proper growth and development (Salisbury and Ross, 1986). In contrast to nitrogen and phosphorus, potassium does not form a stable structural part of any molecule inside the plant cells. Potassium activates the enzymes that synthesize certain peptide bonds (Webster, 1953) and enhances the incorporation of aminoacids into protein (Webster, 1956). Other enzymes that require potassium (K") as an activator include fructokinase, pyruvic acid kinase and transacetylase (Nason and McElory, 1963). Potassium is essential for most metabolic processes, including glycolysis, oxidative phosphorylation and adenine synthesis (Evans and Sorger, 1966). It is involved in the translocation of solutes moving actively across the sieve plate by electro-osmosis (Salisbury and Ross, 1986) . It plays a role in tissue hydration and thus helps in opening and closing of stomata (Fischer and Hsiao, 1968; Humble and Hsiao, 1969; Webb and Mansfield, 1992). Potassium deficiency results in chlorosis of older leaves first. Its deficiency causes scorching of margin and tip, necrosis, rosette or bushy habit of growth and weakening of stems. It also causes reduction in protein synthesis (Hewitt, 1963).

Chundawat (1975) studied at Jaipur (Rajasthan) the effect of 3 levels each of nitrogen (0, 30 and 60 kg N/ha, phosphorus (0, 13.0 ^nd 26.1 kg P/ha) and potassium (0, 2 4.9 and 4 9.8 kg K/ha) on yield of mustard (Brassica juncea var. RL-18). Half of nitrogen and full amount of phosphorus and potassium were drilled at sowing. The remaining half of nitogeh was top- dressed at first irrigation. They found that application of 60 kg of N and 26.1 kg P/ha was economical. However, the increase in yield with increasing dose of potassium was not significant and response to potassium was restricted to 24.9 kg K/ha).

2.2: Effect of zinc on Mustard

Two varieties (Early Mustard and S-9) were evaluated against six Zn levels (0, 2, 4, 6, 8 and 10 kg Zn ha^{-1}). Significant improvements in the plant growth, seed yield and oil contents increased with increasing Zn levels. The results revealed that there was a significant improvement in the growth, seed yield and oil content with increasing Zn levels, irrespectively. The highest Zn level of 10 kg ha^{-1} resulted 216 cm plant height, 10.86 branches plant, took 55.66 days to initiate flowering, 574.50 pods $plant^{-1}$, 17.61 g weight of seeds $plant^{-1}$, 3.63 g seed index, 2037.20 seed yield kg ha^{-1} and 36.80 percent oil as the highest output. In case of varieties, S-9 ranked 1st with 216.50 cm plant height, 10.84 branches $plant^{-1}$, took 56.33 days to initiate flowering, 581.11 pods $plant^{-1}$, 17.82 g weight of seeds $plant^{-1}$, 3.66 g seed index, 1960.30 seed yield kg ha^{-1} and 36.80 percent oil content; while variety Early Mustard resulted 186.56 cm plant height, 9.25 branches $plant^{-1}$, took 52.72 days to initiate flowering, 484.67 pods $plant^{-1}$, 14.50 g weight of seeds $plant^{-1}$, 2.90 g seed index, 1677.90 seed yield kg ha^{-1} and 35.13 percent oil content. It is suggested that for achieving economically higher seed yields in mustard, the Zn application to mustard may be done at the rate of 8 kg ha^{-1} . Moreover, variety S-9 may preferably grow for obtaining higher seed and oil contact yields.

An experiment was carried out in the farmer’s field at the MLT site Tularampur, Narail (AEZ-11) during the rabi season of 2011-12 to evaluate the performance of newly released mustard varieties to Zn fertilization. Three levels of zinc 2, 3 and 4 kg/ha from zinc sulphate was used in BARI Sharisha-14. The experiment was carried out in a tree with 6 dispersed replications. Response of mustard to zinc fertilizer was significantly evident for yield. The highest yield (1.42 t/ha) was obtained from T1 (3 kg Zn/ha) which was statistically higher than T2 (4 kg Zn/ha) yielding 1.37 t/ha. Both the treatments gave higher yields over the control. From the economic analysis, the highest gross margin was observed (Tk. 47695/ha and Tk. 44595/ha) and highest benefit cost ratio (BCR) (1.57 and 1.45) obtained from T2 treatment followed by T3 treatment, respectively.

A field experiment was conducted during 2014-15 with mustard (Brassica spp. L.) as a test crop under irrigated conditions on sandy clay loam soils with 4 levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and 3 levels of zinc (0, 2.5 and 5.0 kg ha^{-1}) in Factorial Randomized Block Design with three replications. Seed and stover yield increased significantly upto 30 kg S ha-1 and 5.0 kg Zn ha^{-1} application. Maximum seed yield (2011.7 kg ha^{-1}) observed with S3 x Zn2 which was significantly higher over rest all the treatment combinations except S3 x Zn2 and S2 x Zn2 treatments. The maximum net return (Rs. 46475 and 45537) was obtained from S3 (45 kg S ha^{-1}) x Zn2 (5.0 kg Zn ha^{-1}) treatments and it was higher than all other treatments. Whereas, maximum B:C ratio (3.71) was obtained from S2 (30 kg S ha-1) x Zn2 (5.0 kg Zn ha-1).

A field experiment was conducted to study the effect of zinc and boron levels on yield, quality and nutrient uptake in mustard under Northern transition zone of Karnataka during rabi, 2017 at MARS, UAS, Dharwad with 10 treatments. The treatment comprised of two levels of zinc (10 kg ha^{-1} and 20 kg ha^{-1}) and two levels of boron (1 kg ha^{-1} and 2 kg ha^{-1}) and their combinations. These treatments were compared with RDF + FYM @ 5 t ha^{-1} and RDF (60:50:40 N: P2O5: K2O) alone. The treatments were replicated thrice in a randomized block design. The experimental soil being deficient in zinc and boron, good response of crop to the applied zinc and boron was noticed. Application of ZnSO4 @ 20 kg ha^{-1} along with borax @ 2 kg ha^{-1} recorded higher seed yield (1973 kg ha^{-1}), oil content (37.08 %), oil yield (731 kg ha^{-1}), uptake of zinc (242 g ha^{-1}) and boron (76 g ha^{-1}) were noticed over RDF + FYM alone. However, which was on par with application of RDF + ZnSO4 @ 20 kg ha^{-1} + Borax @ 1 kg ha-1 and RDF + ZnSO4 @ 10 kg ha^{-1} + Borax @ 2 kg ha.

Mustard (Brassica campestris L.) cv. T9 was grown in refined sand at three levels of boron (B), deficient (0.0033 ppm), normal (0.33 ppm), and excess (3.3 ppm), each at three levels of zinc (Zn), low (0.00065 ppm) adequate (0.065 ppm), and high (6.5 ppm). The B deficiency effects were accentuated by low zinc viz., the decreased biomass, B and Zn concentrations in leaves and seeds and the activity of carbonic anhydrase and accumulation of reducing sugars and stimulated activities of peroxidase, ribonuclease, and acid phosphatase in B deficient leaves were aggravated further. Synergism was also observed between the two nutrients when both B and Zn were in excess together as excess B accelerated the effects of high Zn by lowering further the reduced biomass, economic yield, and carbonic anhydrase activity and raised further the increased concentration of B and Zn in leaves and seeds, reducing sugars and activity of peroxidase obtained in excess Zn. In mustard, additive effects of high Zn and low B was reflected when high Zn increased the reduced biomass, seed yield, leaf B, and decreased the stimulated activities of peroxidase, ribonuclease, acid phosphatase, and high concentration of non-reducing sugars to some extent in low B.

A field experiment was conducted in pot-culture of Department of Soil Science and Agril. Chemistry, CSAUA&T, Kanpur (U.P.), during Rabi season 2016-17 to study the Effect of zinc and sulphur on yield, nutrient uptake and quality characteristics of mustard cv. Varuna. The 7 treatments consisted of T1: Control, T2: 100% RDF (80:60:40) + S 40 Kg, T3: 100% RDF+Zn 5kg, T4: 100% RDF+Zn 5kg+S 40kg, T5:100% RDF + FYM5 ton + Zn 5kg, T6: 100% RDF + FYM 5 ton + S40kg T7: 100% RDF + FYM 5 ton + Zn 5 kg + S 40kg. The content of all nutrients increased with integration of FYM, in comparison to control. It was observed that the plant height, No. of primary branches, No. of secondary branches, number of siliqua plant-1 , number of seed siliqua-1 , and test weight (gm) increased with integration of FYM. The maximum plant hight (cm) No. of Primary branches, No. of secondary branches No. of siliqua/plant No. of seed/siliqua and test weight (gm) treatment combination were recorded on T7 100% RDF +5 ton FYM+ S 40 kg+Zn 5 kg (156.5, 6.25, 13.75, 267.25, 14.75 and 4.70) followed by T6: 100% RDF + FYM 5 ton + S40 kg (154.25, 5.50, 13.50, 262.25, 14.00 and 4.59) and T5:100% RDF + FYM5 ton + Zn 5kg, (151.25, 5.47, 12.75, 258.50, 13.50 and 4.46) respectively. The maximum seed and stover yields increased with integration of Farm Yard Manure i.e. T7 100% RDF +5 ton FYM + Zn 5 kg + S 40 kg 21.21 q ha-1 and 47.87q ha-1 , Followed by T6: 100% RDF + FYM 5 ton + S40 kg (18.91 and 43.67 q ha-1) and T5:100% RDF + FYM5 ton + Zn 5kg, (18.51 and 42.51 q ha-1) respectively computed 57.22% and 36.12 % higher than control. The maximum economic benefits of gross realization, net realization along with highest BCR of 2.60:1.

A field experiment was conducted on Pot culture house of Department of Soil Science and Agricultural Chemistry at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the rabi season 2016-17, In the present experiment 8 treatments T1 (Control), T2 (100% RDF) , T3 (100% RDF+S30), T4 (100% RDF+Zn5), T5 (125% RDF), T6(125% RDF+S30), T7 (125% RDF+Zn5), T8 (150% RDF), were laid out in Randomized Block Design(RBD) with four replication. Mustard variety Pusa Bold was taken for study. The results revealed that the Yield (grain and stover yield) and their attributing characteristics of mustard respond significantly with the different treatment combination. The highest grain (20.11 q/ha) and stover yield (43.13 q/ha) was obtained in T7 (125% RDF+Zn5). The treatment T7 cause 32.72 % increase in mustard grain yield and 14.22% increase in stover yield over control. The treatment combination T7 (125% RDF+Zn5) gave the best result in terms of yield and their attributing characteristics

CHAPTER III

MATERIALS AND METHODS

This experiment was conducted on Brassica with 3 doses of potassium (k) and 3doses of zinc (zn) in the rabi season of December 2020 to March 2021 to evaluate the performance of different doses of K and Zn fertilizer on growth and yield of mustard in respect of growth and yield performance.

3.1 Description of the experimental site:

3.1.1 Experimental period

The field experiment was conducted during the period of November 2020 to March 2021.

3.1.2 Experimental location

The present study was conducted in the Experimental Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is 23074/N latitude and 90035/E longitude with an elevation of 8.2 meter from sea level. A map of the experimental location presented in Appendix I.

3.1.3 Soil characteristics

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter 5.6 and 0.78%, respectively and the the soil composed of 26% sand, 43% silt, 31% clay (Appendix II).

3.1.4 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest of the year. During the experimental period the maximum temperature (31.7^0 C) was recorded in the month of March 2021, whereas the minimum temperature (25^0 C) in December 2020. The highest humidity (69%) was recorded in the month of December, 2020, while the highest rainfall (47 mm) was recorded in February 2021. The monthly average temperature, humidity, rainfall and sunshine hour during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix III.

3.2 Factors of the experiment

Factor A: Level of potassium

K_0 = 0 kg ha-1 (control)

K_1 = 55 kg ha^{-1}

K_2 = 65 kg ha^{-1}

B: Level of Zinc

Zn_0 = 0 kg ha^{-1} (control)

Zn_1 = 1.5 kg ha^{-1}

Zn_2 = 2.5 kg ha^{-1}

3.2.1 Experimental details

The treatments comprised of 9 different doses of potassium and zinc fertilizer.

3.2.2 Treatment combination

There are 9 treatment combinations of different level of potassium and zinc used in the experiment under as following:

T_1 (K_0Zn_0) = Control (without K and Zn application)

T_2 (K_0Zn_1) = 0 kg K ha^{-1}+ 1.5 kg Zn ha^{-1}

T_3 (K_0Zn_2) = 0 kg K ha^{-1} + 2.5 kg Zn ha^{-1}

T_4 (K_1Zn_0) = 55 kg K ha^{-1} + 0 kg Zn ha^{-1}

T_5 (K_1Zn_1) = 55 kg K ha^{-1} + 1.5 kg Zn ha^{-1}

T_6 (K_1Zn_2) = 55 kg K ha^{-1} + 2.5 kg Zn ha^{-1}

T_7 (K_2Zn_0) = 65 kg K ha^{-1} + 0 kg Zn ha^{-1}

T_8 (K_2Zn_1) = 65 kg K ha^{-1} + 1.5 kg Zn ha^{-1}

T_9 (K_2Zn_2) = 65 kg K ha^{-1} + 2.5 kg Zn ha^{-1}

3.2.3 Experimental design and layout

The one factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block contained 9 plots altogether in the experiment. The size of each plot was 2m × 1.8m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.3 Growing of crops

3.3.1 Seed collection

BARI Sharisha 15, a medium yielding and short duration variety of mustard (Brassica rapa) developed by BARI, Dhaka was used as experiment crop. The seeds were collected from BARI, Gazipur, Dhaka.

3.3.2 Soil Collection

Soil samples from the experimental field were collected before land preparation and after harvesting yields to a depth of 0-15 cm from the surface of the basis of composite sampling method. The collected soil was air dried, ground and passed through a 2-mm sieve and stored in a clean, dried plastic container for physical and chemical analysis.

3.3.3 Land preparation

The experimental plot was opened on 20 November 2020, with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed for three times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil. Finally, land was prepared on 3 December.

3.3.4 Application fertilizers

Fertilizers were applied to the experimental plot considering the recommended fertilizer doses (BARC, 2018) and as per treatment of the experiment.

Name of Nutrients	Name of Fertilizers	Rate of Application (kg/ha)
Nitrogen (N)	Urea,	250
Phosphorus (P)	Triple Super Phosphate	170
Potassium (K)	Muriate of Potash	As per treatment
Zinc (Zn)	Zinc sulphate	As per treatment
Boron (B)	Boric acid	7.5
Sulphur(S)	Gypsum	14

3.3.5 Seed sowing

The seeds of mustard variety were sown on 3 December 2020, in rows in the furrows having a depth of 2-3 cm.

3.4 Intercultural operations:

3.4.1 Thinning

Seeds germination started at 03 December, 2020, Thinning was done two times; first thinning was done at 10 DAS and second was done at 22 DAS to maintain optimum plant population in each plot as per the treatment of plant density.

3.4.2 Irrigation and weeding

Irrigation was provided for two times after seed sowing and before flowering to all experimental plots equally. The crop field was weeded before providing irrigation.

3.4.3 Protection against insect and pest

At early stage of growth few worms (Agrotis ipsilon) infested the young plants and at later stage of growth pod borer (Maruca testulalis) attacked the plants. Ripcord 10 EC was sprayed at the rate of 1 ml with 1-liter water for two times at 16 days' interval after seedlings germination to control the insects.

3.4.4 Crop sampling and data collection

10 plants from each treatment and each replication were randomly selected and marked with sample card. Plant height, branches $plant^{-1}$ and total dry matter content was recorded from selected plants at an interval of 25 days started from 40 DAS to 60 DAS and other parameters were recorded during harvest and as post-harvest operations.

3.4.5 Harvest and post-harvest operations

Harvesting was done at 03 March 2021 when 90% of the siliqua became brown in color which was estimated by eye observation. The matured plant was harvested manually.

3.5 Data collection

The following data were recorded

1. Plant height (cm)

2. Number of branches $plant^{-1}$

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

4. Number of siliqua $plant^{-1}$

5. Length of siliqua (cm)

6. Number of seeds $silique^{-1}$

7. Weight of 1000 seeds (g)

8. Seed yield $hectare^{-1}$(t)

9.Stover yield $hectare^{-1}$(t)

10.Biological yield $hectare^{-1}$(t)

11.Harvest Index (%)

3.5.1 Procedure of data collection:

3.5.2 Plant height (cm)

The plant height was measured at 25, 45 and 60 DAS with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.5.3 Number of branches plant^{-1}

The number of branches plant-1 was counted at 25, 40 and 60 DAS from selected plants. The average number of branches plant-1 was determined and recorded with proper estimation.

3.5.4 Number of leaves plant^{-1}

The number of leaves plant-1 was counted at 25, 45 and 60 DAS from selected plants. The average number of leaves plant-1 was determined and recorded.

3.5.5 Number of siliqua plant^{-1}

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.5.6 Length of siliqua (cm)

Length of siliqua was taken from randomly selected ten siliqua and the mean length was expressed on siliqua-1 basis.

3.5.7 Number of seeds silique^{-1}

The number of seeds silique^{-1} was recorded from randomly selected 15 siliqua at the time of harvest. Data were recorded as the average and express in seeds siliqua-1.

3.5.8 Weight of 1000 seeds (g)

1,000 cleaned, dried seeds of mustard were counted from each harvest sample and weighed by using a digital electronic balance and weight was expressed in gram (g)

3.5.9 Seed yield hectare^{-1}(t)

The seeds collected from 3.6 (2 m × 1.80m) square meter area of each plot were sun dried properly, weighted and data were recorded. The seeds yield of each plot were converted into yield hectare^{-1} and express in seed yield of t ha^{-1}.

3.5.10 Stover yield hectare^{-1}(t)

The stover collected from 3.6 (2 m × 1.8 m) square meter area of each plot was sun dried properly, weighted and data were recorded. The stover yield of each plot were converted into yield hectare^{-1} and express in stover yield of t ha^{-1}.

3.6 Biological yield

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula: Biological yield = Seed yield + Stover yield.

3.7 Harvest index (%)

The harvest index was calculated from the ratio of seed yield to biological yield (seed yield + stover yield) and expressed in terms of percentage.

3.8 Methods for Soil Analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, PH, total N and available P and K contents. The soil samples were analyzed by the following standard methods as follows:

3.8.1 Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method. The textural class was determined by plotting the values of 27.32% sand, 51.75% silt and 20.93% clay using Marshall's Triangular co-ordinate as designated by USDA.

3.8.2 Organic carbon (%)

Soil organic carbon was estimated by Walkley and Black's wet oxidation method as outlined by Jackson (1973).

P^H	5.99
Organic Matter(%)	0.84
Total N(N%)	0.17
Available P	12.08
Available S	20.09

3.8.3 C/N ratio

The C/N ratio was calculated from the percentage of organic carbon and total N.

3.8.4 Soil organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page et al., 1982). Soil organic matter content was calculated by multiplying the percent value of organic carbon with the Van Bemmelen factor, 1.724.

% organic matter = % organic carbon × 1.724

3.8.5 Soil pH

The pH of the soil was determined with the help of a glass electrode pH meter using Soil: water ratio 1:2.5 (Jackson, 1973).

3.8.6 Total nitrogen (%)

Total nitrogen content in soil was determined by Kjeldahl method by digesting the soil sample with conc. H_2SO_4, 30% H_2O_2 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 10:1:0.1) followed by distillation with 40% NaOH and by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Black, 1965).

The amount of N was calculated using the following formula:

$\% N = (T-B) \times N \times 0.014 \times 100 / S$

Where,

T = Sample titration (ml) value of standard H2SO4

B = Blank titration (ml) value of standard H2SO4

N = Strength of H2SO4

S = Sample weight in gram

3.8.7 Available sulphur (ppm)

Available S in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page et al., 1982). The S content in the extract was determined turbid metrically and the intensity of turbid was measured by spectrophotometer at 420 nm wave length.

3.8.8 Available Phosphorus (ppm)

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ solution, pH 8.5 (Olsen et al., 1954). Phosphorus in the extract was measured spectrophotometrically after development of blue color (Black, 1965). It was determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page et al. 1982).

3.8.9 Exchangeable Potassium (meq/100 g soil)

Exchangeable potassium (K) content of the soil sample was determined by flame photometer on the NH_4OAc extract (Black, 1965).

3.9 Statistical analysis

The data gathered for different parameters were statistically analyzed the morphology and yield of mustard as influenced by potassium and zinc. The mean values of all the recorded parameters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment combinations of means was estimated by Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of potassium and zinc different levels of with population density on growth and yield of mustard (BARI Sharisha-15). The results have been presented and discussed, and possible explanations have been given under the following headings:

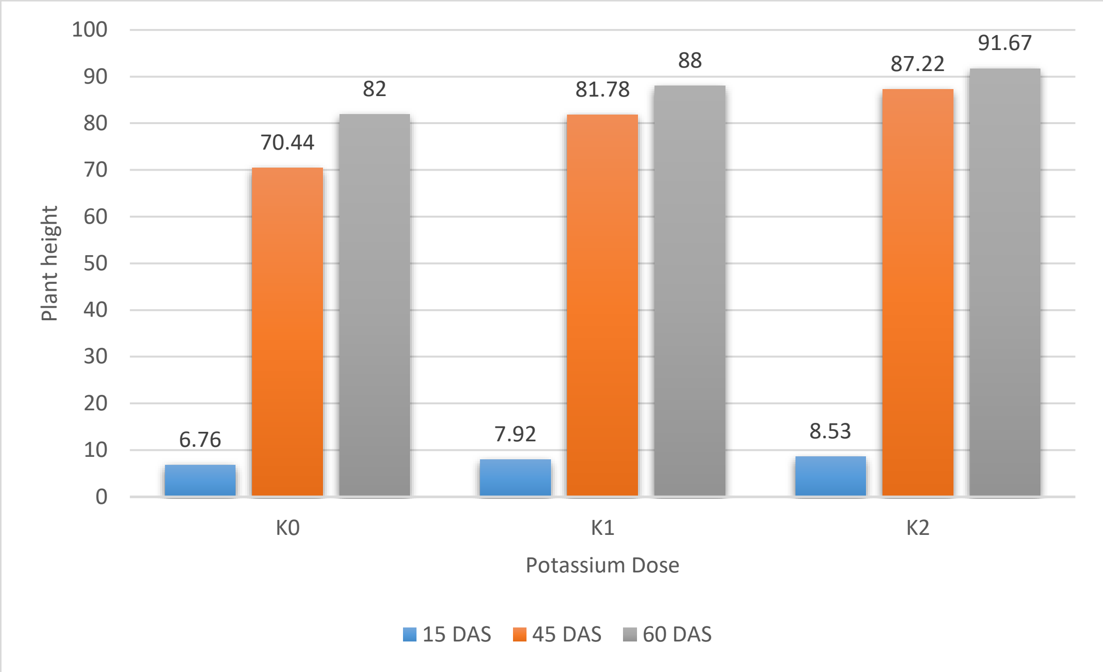
4. Growth parameters

4.1 Plant height

The results of this study showed that potassium (K) levels showed significant effect on rapeseed plant height (Fig. 1). The plant height of mustard cv. BARI Sarisha-15 was significantly influenced with the application of potassium fertilizer. It was observed that in case of plant height significant difference was found at 15, 45, 60 DAS.

The height of mustard plant significantly influenced at 15, 45, 60 days after sowing (DAS) (Fig. 1), The tallest plant (8.53, 87.22 and 91.67 cm at 15, 45, and 60 DAS, respectively) was recorded with T_4 treatment. In contrast, the shortest plant (6.76, 70.44 and 82 cm at 15, 45, and 60 DAS, respectively) was recorded from T_1 (Control condition).

Figure 1: Effect of potassium (K) on the Plant height of mustard

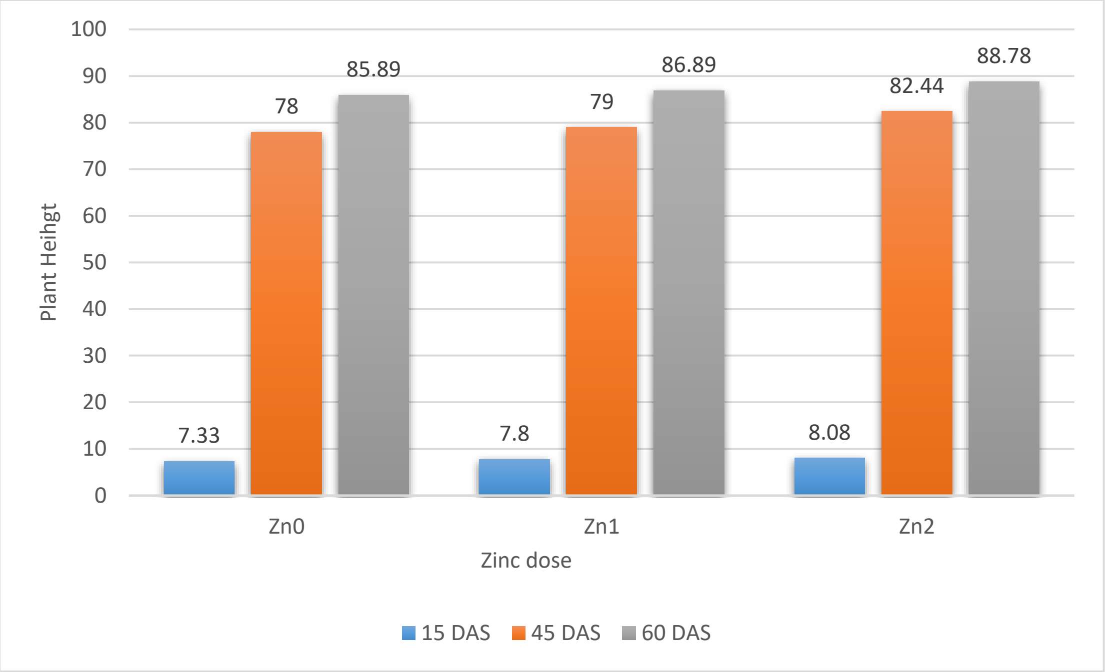


Where: K_0 = Control condition K_1 = 55 kg ha^{-1} K_2 = 65 kg ha^{-1}

The K fertilizer's requirements can differ very much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc. The results suggest that higher doses of K increase mustard plant height.

There is significant difference among the different doses of Zinc. The tallest plant (8.08, 82.44 and 88.78 cm, at 15, 45, and 60 DAS, respectively) was found in treatment T_3 and shortest plant (7.33, 78.00 and 86 cm at 15, 45 and 60 DAS, respectively) was found in T_1 (Control condition). Data pertaining to Fig. 2 revealed that plant height was not significantly affected by different doses of Zinc. However, plant height increased with increasing levels of Zinc up to higher level.

Figure 2: Effect of Zinc (Zn) on the Plant height of mustard



Where:

Zn_0= 0 kg/ha Zn_1= 1.5 kg/ha Zn_2= 2.5 kg/ha

4.1.1 Effect of potassium (K) and zinc (Zn) on the plant height (cm) of mustard

Differences in plant height at all the stages of growth were significant due to different doses of potassium and zinc (Table 1). Plant height increased with increasing doses of potassium and zinc at all the stages of growth. At 60 DAS among the different doses of potassium and zinc, T_9 @ 65 kg (K) and 2.5 kg (Zn) ha^{-1} showed the highest plant height (93.67cm), on the other hand, the lowest plant height (80.66cm) was observed in the T_1 treatment where no fertilizer was applied. Probably, potassium and zinc ensured favorable condition for plant growth as a result maximum growth was occurred.

Table 1: Effect of different doses of potassium and zine on plant height at different days after sowing (DAS) of mustard.

Treatments	Plant height (cm)		
	15 DAS	45 DAS	60 DAS
T_1	6.16g	68f	80.66e
T_2	7f	69.33f	81.67de
T_3	7.13f	74.00e	83.33d
T_4	7.68e	80.00d	86.33c
T_5	7.90d	82.33c	88.33bc
T_6	8.18c	83.00c	89.33b
T_7	8.15c	86.00b	90.67b
T_8	8.50b	85.33b	90.67b
T_9	8.93a	90.33a	93.67a
LSD (0.05)	0.18	1.83	2.34
CV%	1.37	1.33	1.55

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

Where: T_1 (K_0Zn_0) = Control (without K and Zn application), T_2 (K_0Zn_1) = (0 kg K/ha+ 1.5 kg Zn/ha), T_3 (K_0Zn_2) = (0 kg K/ha + 2.5 kg Zn/ha), T_4 (K_1Zn_0) = (55 kg K/ha + 0 kg Zn/ha), T_5 (K_1Zn_1) = (55 kg K/ha + 1.5 kg Zn/ha), T_6 (K_1Zn_2) = (55 kg K/ha + 2.5 kg Zn/ha), T_7 (K_2Zn_0) = (65 kg K/ha + 0 kg Zn/ha), T_8 (K_2Zn_1) = (65 kg K/ha + 1.5 kg Zn/ha), T_9 (K_2Zn_2) = (65 kg K/ha + 2.5 kg Zn/ha)

4.2 Number branches plant^{-1}

The Nitrogen management had significant effect on number of primary branches of plant. At 60 DAS, produced the highest branches plant^{-1}. The maximum number of branches per plant (6.57 and 8.82 in 45 and 60 DAS respectively) was produced by 65 kg K ha^{-1}. Control produced the minimum number of branches per plant (5.94 and 8.12 in 45 and 60 DAS respectively). Altogether, it suggests that K involve in initiating branches by sprouting lateral buds of mustard plants.

Table 2: Effect of potasssium (K) on the number of branches per plant of mustard

Treatments	No. of branches	
	45DAS	60 DAS
T_0	5.94 c	8.12 c
T_1	6.26 b	8.49 b
T_2	6.57 a	8.82 a
LSD (0.05)	.085	0.097
CV (%)	1.35	1.55

Where:

T_1= K_0 (Control condition), T_4= K_1 (55 kg/ha), T_7= K_2 (65 kg/ha)

The different levels of Zn had significant effect on number of primary branches per plant. The maximum number of branches per plant (8.57) was produced by 2.5 kg Zn ha^{-1}. Control produced the minimum number of branches per plant (8.33).The Zn influenced significantly on number of primary branches per plant (Table 3).

Table 3: Effect of Zinc (Zn) on the number of branches per plant of mustard

Treatments	No. of branches	
	45DAS	60 DAS
T_0	6.18 b	8.33 c
T_1	6.24 b	8.43 b
T_2	6.36 a	8.57 a
LSD (0.05)	0.085	0.097
CV (%)	1.35	1.55

Where:

Zn_0= control Zn_1= 1.5 kg/ha Zn_2= 2.5 kg/ha

Different treatments of potassium and zine fertilizer showed insignificant variations in respect of number of primary branches plant^{-1} (Table 4). At 60 DAS among the different doses of potassium and zine, 65 kg potassium and 2.5kg zine ha^{-1} showed the highest number of primary branches plant (9.10). On the contrary, the lowest number of primary branches plant^{-1} (8.0) was recorded in the T_1 treatment. The decrease number of branches/plant may be due to negative effects of potassium and zine on the vegetative growth and accumulation of materials that helped proper growth and development of the mustard plant.

Table 4: Effect of different doses of potassium and zine on Number of branches at different days after sowing (DAS) of mustard.

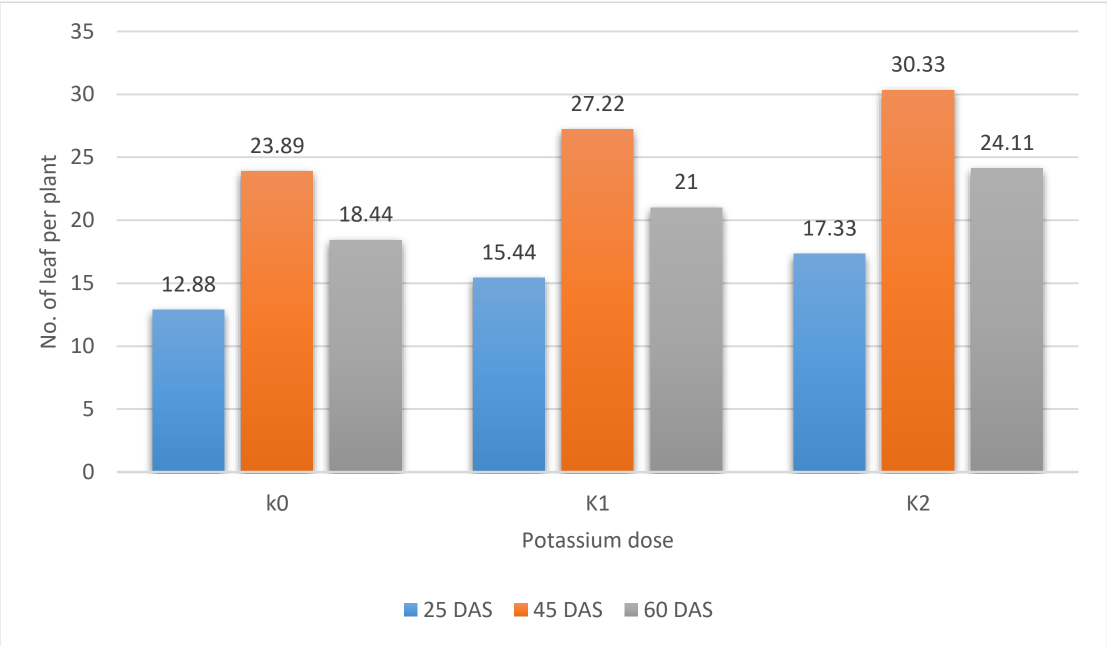
Treatments	Number of Branches	
	45 DAS	60 DAS
T_1	5.9f	8.0f
T_2	5.93f	8.11f
T_3	6.00f	8.16ef
T_4	6.17e	8.33de
T_5	6.30de	8.40d
T_6	6.33cd	8.43cd
T_7	6.46bc	8.58c
T_8	6.50b	8.76b
T_9	6.73a	9.10a
LSD (0.05)	0.14	0.16
CV%	1.35	1.55

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

4.3 Number of leaves plant^{-1}

The K showed significant variation in the number of leaves per plant (Figure 3). The maximum number of leaves per plant (17.33, 30.33 and 24.11 at 25, 45 and 60 DAS respectively) was produced by 65 kg K/ha and without K produced the lowest number of leaves per plant (12.88, 23.89 and 18.44 in 25, 45 and 60 DAS respectively). It is reported that better growth and development of crop depend on a good number of leaves and producing more foliage related to the yield of rapeseed (through higher siliquae yield and stover yield) to the seed production those are linked to use of amount of K fertilizer and suggesting that the greater number of leaf, the greater the photosynthetic area which may result higher seed yield. These indicate number of leaves per plant increased with increasing K levels.

Figure 3: Effect of potassium (K) on the no. of leaf per plant of mustard

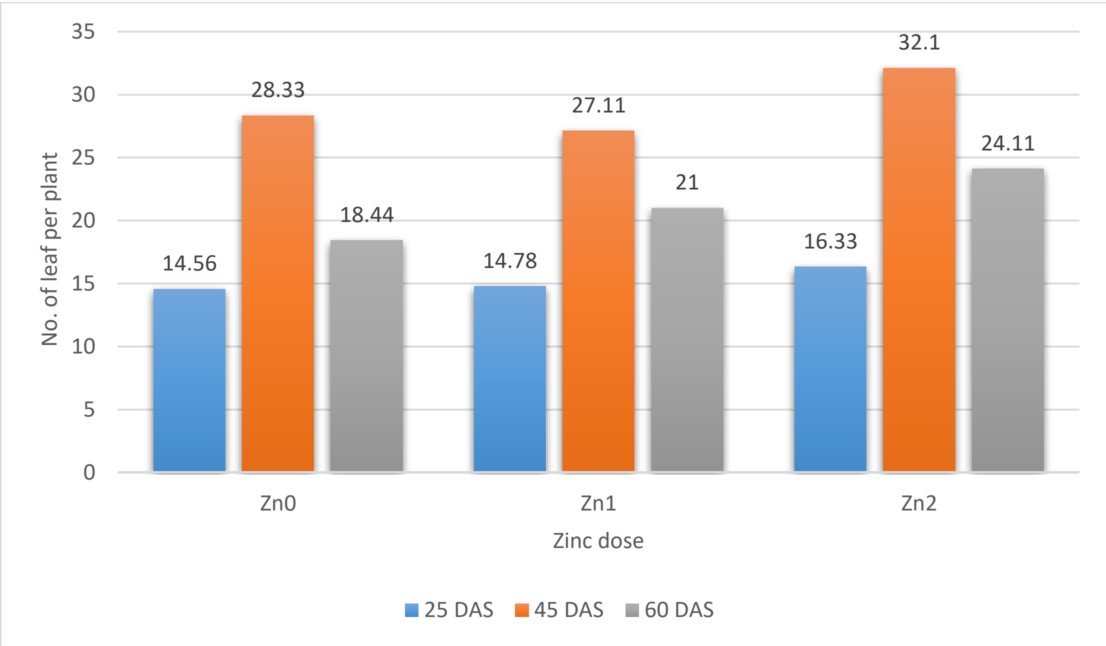


Where:

K_0 = Control condition K_1 = 55 kg/ha K_2 = 65 kg/ha

Number of leaves per plant due to the influence of Zn was significant (table 3). With the 2.5 kg Zn/ha had the highest number of leaves per plant (16.33, 32.1 and 24.11 at 25, 45 and 60 DAS respectively). However, the lowest number of leaves per plant (14.56, 28.33 and 18.44 in 25, 45 and 60 DAS respectively) was obtained from the control. So, Zn has important role on increasing number of rapeseed leaves.

Figure 4: Effect of Zinc (Zn) on the no. of leaf per plant of mustard



Where:

Zn_0= 0 kg/ha Zn_1= 1.5 kg/ha Zn_2= 2.5 kg/ha

Different treatments of potassium and zine fertilizer showed insignificant variations in respect of number of leaves plant^{-1} (Table 5). At 60 DAS among the different doses of potassium and zine, 65 kg potassium and 2.5kg zine ha^{-1} showed the highest number of leaves plant^{-1} (25.66). On the contrary, the lowest number of leaves plant^{-1} (17.66) was recorded in the T_1 treatment.

Table 5: Effect of different doses of potassium and zine on Number of leaves plant^{-1}(cm) at different days after sowing (DAS) of mustard.

Treatments	**Number of leaves plant^{-1}**		
	25 DAS	45 DAS	60 DAS
T_1	11.66e	23.33f	17.66e
T_2	12.66e	23.66ef	18.66b
T_3	14.33d	24.66e	19.00d
T_4	15.33cd	26.33d	20.66c
T_5	15.00cd	27.00d	21.00c
T_6	16.00bc	28.33c	21.33c
T_7	16.66b	28.33c	23.33b
T_8	16.66b	30.66b	23.33b
T_9	18.66a	32.00a	25.66a
LSD (0.05)	1.22	1.26	1.23
CV%	4.65	2.70	3.37

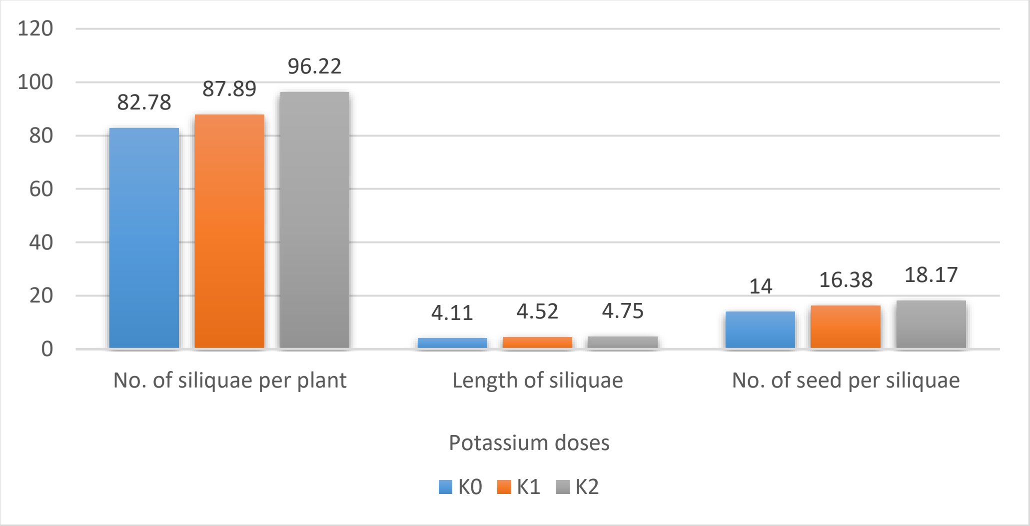
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Where: T_1 (K_0Zn_0) = Control (without K and Zn application), T_2 (K_0Zn_1) = (0 kg K/ha+ 1.5 kg Zn/ha), T_3 (K_0Zn_2) = (0 kg K/ha + 2.5 kg Zn/ha), T_4 (K_1Zn_0) = (55 kg K/ha + 0 kg Zn/ha), T_5 (K_1Zn_1) = (55 kg K/ha + 1.5 kg Zn/ha), T_6 (K_1Zn_2) = (55 kg K/ha + 2.5 kg Zn/ha), T_7 (K_2Zn_0) = (65 kg K/ha + 0 kg Zn/ha), T_8 (K_2Zn_1) = (65 kg K/ha + 1.5 kg Zn/ha), T_9 (K_2Zn_2) = (65 kg K/ha + 2.5 kg Zn/ha)

4.4 Number of siliquae per plant

The number of siliquae per plant of mustard was highly affected by nitrogen rates and their interaction. The K showed significance variation in the number of siliquae per plant (figure 5). The Maximum number siliquae per plant (96.22) was obtained in plots which received 65 kg K ha^{-1}. The minimum number of siliquae per plant (82.78) produced in control condition (no potassium application). These are consistent with the length of siliquae of rapeseed. Here treatment T_3 also gives close result of T_6. The significance difference between T_6 and T_3 is very low.

Figure 5: Effect of potassium(K) on the different growth factor mustard



Where:

K_0= Control K_1= 55 kg/ha K_2= 65 kg/ha

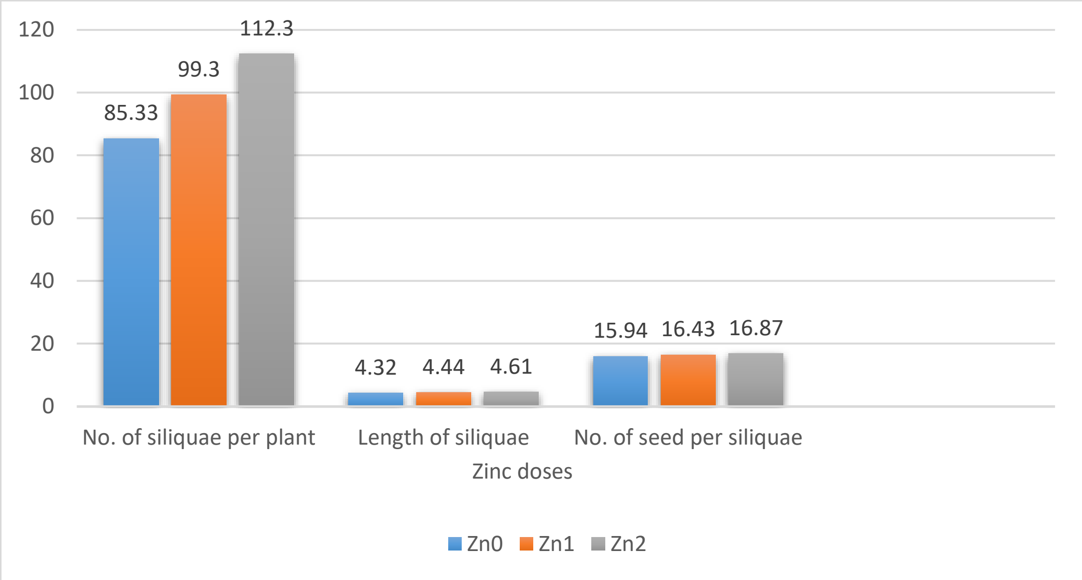
The K showed significant variation in the length of siliquae (figure 5). The longest length of siliquae (4.75 cm) was produced by 65 kg K ha^{-1} whereas K_2 and K_0 treatment produced the shortest length of siliquae (4.11cm).

Siliqua $plant^{-1}$ of mustard showed a statistically significant variation for different potassium and zine levels under this experiment (Table 4). The number of siliqua $plant^{-1}$ enhanced with increasing the doses of potassium and zine and the highest and significant number 104 was obtained with T_8 (65 kg potassium ha^{-1} + 2.5 kg zinc ha^{-1}) whereas lowest siliqua $plant^{-1}$ was 82 and was found in T_0 (control).

4.5 Length of siliquae

There was a significant difference among the Zn doses in the number of siliquae per plant (Figure 6). The maximum number of siliquae per plant (92.00) was produced in Zn_2 or with 2.5 kg Zn ha^{-1} and the minimum number of siliquae per plant (85.33) was produced in Zn_0 or control condition. There was no significant difference among the Zn treatments in the length of siliquae (figure 6).

Figure 6: Effect of Zinc (Zn) on the different growth factor of mustard



Where:

Zn_0= Control Zn_1= 1.5 kg/ha Zn_2= 2.5 kg/ha

Length of siliqua of mustard showed a statistically significant variation for different potassium and zine levels under this experiment (Table 4). The length of siliqua enhanced with increasing the doses of potassium and zine and the highest and significant number 4.80 cm was obtained with T_8 (65 kg potassium ha^{-1} + 2.5 kg zinc ha^{-1}) whereas lowest length of siliqua was 3.86 cm and was found in T_0 (control).

4.6 Number of seeds silique^{-1}

Siliqua plant^{-1} of mustard showed a statistically significant variation for different potassium and zine levels under this experiment (Table 6). The number of seeds silique^{-1} enhanced with increasing the doses of potassium and zine and the highest and significant number 18.83 was obtained with T_9 (65 kg potassium ha^{-1} + 2.5 kg zinc ha^{-1}) whereas lowest number of seeds silique^{-1} was 14.40 and was found in T_1 (control).

Table 6: Effect of different doses of potassium and zine on Number of siliqua $plant^{-1}$, Length of siliqua (cm) and Number of seeds $silique^{-1}$ different days after sowing (DAS) of mustard.

Treatments	Number of siliqua $plant^{-1}$	Length of siliqua (cm)	Number of seeds $siliqua^{-1}$
T_1	82.00d	3.86g	14.40h
T_2	83.00d	4.06f	14.73g
T_3	83.33d	4.40e	14.97g
T_4	86.33c	4.40e	15.93f
T_5	88.67c	4.53d	16.40e
T_6	88.67c	4.63c	16.83d
T_7	87.67c	4.70bc	17.50c
T_8	97.00b	4.73ab	18.17b
T_9	104a	4.80a	18.83a
LSD (0.05)	2.83	0.08	0.31
CV%	1.84	1.07	1.10

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

Where: T_1 (K_0Zn_0) = Control (without K and Zn application), T_2 (K_0Zn_1) = (0 kg K/ha+ 1.5 kg Zn/ha), T_3 (K_0Zn_2) = (0 kg K/ha + 2.5 kg Zn/ha), T_4 (K_1Zn_0) = (55 kg K/ha + 0 kg Zn/ha), T_5 (K_1Zn_1) = (55 kg K/ha + 1.5 kg Zn/ha), T_6 (K_1Zn_2) = (55 kg K/ha + 2.5 kg Zn/ha), T_7 (K_2Zn_0) = (65 kg K/ha + 0 kg Zn/ha), T_8 (K_2Zn_1) = (65 kg K/ha + 1.5 kg Zn/ha), T_9 (K_2Zn_2) = (65 kg K/ha + 2.5 kg Zn/ha)

4.7 Yield and yield contributing parameters

4.7.1 1000- Seed weight

The application of potassium was not influenced significantly on the thousand seed weight (Table 7). The maximum thousand seed weight (3.46 g) was produced by K_2, and K_0 produced the lowest thousand seed weight (3.02 g).

Table 7: Effect of potassium (K) on yield and thousand seed of mustard

Treatments	1000 seed weight (g)	Yield (t/ha)
K_0	3.02 c	1.22 c
K_1	3.20 b	1.37 b
K_2	3.46 a	1.63 a
LSD (0.05)	0.017	0.033
CV (%)	1.07	1.10

Where:

K_0= Control K_1= 50 kg/ha K_2= 65 kg/ha

The weight of thousand seed was not significantly influenced by Zn (Table 8). The highest thousand seed weight (3.28 g) was obtained from Zn_2 treatment. The lowest thousand seed weight (3.17 g) was obtained from without Zn.

Different level of magnesium exhibited statistically significant variation for 1000 seed weight. It increased significantly with higher levels of potassium and zine with the highest (3.54 g) at T_8 treatment comprising of (65 kg potassium ha^{-1} + 2.5 kg zinc ha^{-1}) whereas lowest (3.00) T_0 treatment (Table 5).

Table 8: Effect of Zinc (Zn) on yield and thousand seed of mustard

Treatments	1000 seed weight (g)	Yield (t/ha)
Zn_0	3.17b	1.30 c
Zn_1	3.23 b	1.36 b
Zn_2	3.28 a	1.45 a
LSD (0.05)	0.017	0.033
CV (%)	1.07	1.10

Where: Zn_0= Control Zn_1= 1.5 kg/ha Zn_2= 2.5 kg/ha

4.7.2 Seed yield hectare^{-1} (t)

The different dose of K had significant effect on rapeseed yield per ha (Table 7). The maximum yield of seed per ha (1.63t) was obtained from K_2, 65 kg K ha^{-1} , whereas the minimum yield of seed per hectare (1.22 t) was obtained from K_0, without K. Further increase in K level beyond 65 kg ha^{-1} could not improve the seed yield. These results is consistent with the K-induced increase of growth parameters along with number of siliquae plant^{-1}, and thousand seed weight (Table 7). Therefore, K can enhance the seed yield (t ha^{-1}) of mustard variety BARI sarisha-15.

The total yield of mustard varied significantly due to the application of different levels of Zn fertilizer (Table 8). The highest yield of seed (1.45t ha^{-1}) was obtained from Zn_2, 2.5 kg Zn ha^{-1} while Zn_0 gave the lowest (1.30 t ha^{-1}) yield. This result showed that the yield of mustard increased gradually with the higher doses of Zn fertilizer. Interestingly, this result is consistent with the Zn-induced yield components such as number of siliquae plant^{-1}, thousand seed weight and seed yield (Table 8) rather than growth parameters. Therefore, higher dose of Zn can increase seed yield of rapeseed.

Different level of magnesium exhibited statistically significant variation for seed yield hectare-1. It increased significantly with higher levels of potassium and zine with the highest (1.67t ha^{-1}) at T_9 treatment comprising of (65 kg potassium ha^{-1} + 2.5 kg zinc ha^{-1}) whereas lowest (1.05t ha^{-1}) T_1 treatment (Table 9).

Table 9: Effect of different doses of potassium and zine on Weight of 1000 seeds (gm), Seed yield hectare^{-1} (t) different days after sowing (DAS) of mustard.

Treatments	**Weight of 1000 seeds (gm)**	**Seed yield hectare^{-1} (t/ha)**
T_1	3.00h	1.05h
T_2	3.03gh	1.12g
T_3	3.05g	1.20f
T_4	3.15f	1.26e
T_5	3.20e	1.35d
T_6	3.25d	1.50c
T_7	3.37c	1.60b
T_8	3.47b	1.62ab
T_9	3.54a	1.67a
LSD (0.05)	0.03	0.06
CV%	1.07	1.10

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

Where: T_1 (K_0Zn_0) = Control (without K and Zn application), T_2 (K_0Zn_1) = (0 kg K/ha+ 1.5 kg Zn/ha), T_3 (K_0Zn_2) = (0 kg K/ha + 2.5 kg Zn/ha), T_4 (K_1Zn_0) = (55 kg K/ha + 0 kg Zn/ha), T_5 (K_1Zn_1) = (55 kg K/ha + 1.5 kg Zn/ha), T_6 (K_1Zn_2) = (55 kg K/ha + 2.5 kg Zn/ha), T_7 (K_2Zn_0) = (65 kg K/ha + 0 kg Zn/ha), T_8 (K_2Zn_1) = (65 kg K/ha + 1.5 kg Zn/ha), T_9 (K_2Zn_2) = (65 kg K/ha + 2.5 kg Zn/ha)

CHAPTER V

SUMMARY

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh during rabi season, November 2020 to February 2021, situated under the Modhupur Tract (AEZ-28). The research work was done to investigate the influence of Potassium and zinc application on the growth and yield of mustard. In this experiment, the treatment consisted of three different K levels viz. K_0 = 0 kg K/ha, K_1 = 55 kg K/ha and K_2 = 65 kg K/ha, and three different level of Zinc viz. Zn_0 = 0 kg/ha, Zn_1 =1.5 kg Zn/ha and Zn_2 =2.5 kg Zn/ha. The experiment consisted of two factors. Factor A: Potassium and Factor B: Zinc. There were 9 treatments combinations. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid as a source of N, P, K, S, Zn and B respectively were applied according to treatment and area of experimental unit plot. Urea was applied two equal splits, the first one-half of urea was applied as basal and second one-half was applied at 30 DAS. After emergence of mustard seedlings, various intercultural operations such as thinning, weeding, irrigation, drainage and pest management were accomplished for better growth. The collected data were statistically analyzed for evaluation of the treatment effect (different levels of potassium and Zinc). Results showed that a significant variation among the treatments in respect majority of the observed parameters.

There is significant difference among the different levels of K in respect of almost all parameters. The tallest plant (91.67 cm) was recorded with K_2 (65 kg K ha^{-1}). The tallest plant height 8.53, 87.22 and 91.67 cm, respectively at 15, 45 and 60 DAS were produced with K_2 treatment. The maximum number of leaves per plant (25.45) was produced by K_2 (65 kg N ha^{-1}).The maximum number of branches per plant (6.57 and 8.82 at 45 DAS and 60 DAS respectively) was produced by 65 kg K ha^{-1}. The maximum number siliquae per plant (96.22) was obtained in plots which received 65 kg K ha^{-1}. The longest length of siliquae (4.75 cm) was produced by K_2, 65kg K ha^{-1}. The maximum number seed per siliquae (18.17) was obtained in plots which received 65 kg K ha^{-1}. The maximum thousand seed weight (3.46 g) was produced by K_2. The

maximum yield of seed per hectare (1.63t) was obtained from K_2 (65 kg K ha^{-1}, whereas the minimum yield of seed per hectare (1.22 t) was obtained from K_0 (without K). For all parameters treatment K_1 gives nearest result with treatment K_2.

Plant height, number of leaves, branches per plant and length of slliquae was influenced by statistically significant application of Zn. The tallest plant (88.78 cm) was produced with Zn_2 (2.5 kg Zn ha^{-1}). The maximum number of leaves per plant (32.1), number of primary branches per plant (6.36 and 8.57 in 45 DAS and 60 DAS respectively), length of siliquae (4.61 cm) was produced with Zn_2, 2.5 kg Zn ha^{-1}. The maximum number of siliquae per plant (112.3), Number of Seed per pod (16.87) and thousand seed weight (3.28g) was produced in Zn_2, 2.5 kg Zn ha^{-1}. The highest yield of seed (1.45 t/ha) was obtained from Zn_2, 2.5kg Zn ha^{-1} while Zn_0 gave the lowest (1.30 t $ha^{-1)}$ yield. For all parameters treatment Zn_1 gives nearest result with treatment Zn_2.

The combinations of K and Zn had significant effect on almost all parameter. The tallest plant (93.67cm) was found in T_9 (K_2Zn_2 treatment combination, 65 kg K ha^{-1} and 2.5 kg Zn ha^{-1}). The maximum number of leaves per plant (25.66), number of branches per plant (6.73 and 9.0) at 45 DAS and 60 DAS respectively), length of siliquae (4.80 cm) was found in T_9 (K_2Zn_2 treatment combination, 65 kg K ha^{-1} and 2.5 kg Zn ha^{-1}). The maximum number of siliquae per plant (104), number of seed per siliquae (18.83), thousand seed weight (3.54 g) was found in T_9 (K_2Zn_2, 65 kg K ha^{-1} with 2.5 kg Zn ha^{-1}). The highest yield of seed per hectare (1.67 tones) was obtained from T_9 (K_2Zn_2 treatment combination, 65 kg K ha^{-1} and 2.5 kg Zn ha^{-1}). The lowest yield of seed per hectare (1.05 tones) was obtained from treatment 1 (control condition). For all parameters treatment 8 (combination of 65 kg K ha^{-1} and 1.5 kg Zn ha^{-1}) gives almost similar result with treatment T_9. Significance difference between T_9 and T_8 is very low. But T_9 (combination of 65 kg K ha^{-1} and 2.5 kg Zn ha^{-1}) is more significance.

CHAPTER VI

CONCLUSION

Based on the results it can be concluded that, T_9 (65 kg potassium ha^{-1}+2.5 kg zinc ha^{-1}) showed comparatively high yield (1.67 ton ha^{-1}) for the production of mustard under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka and similar environment elsewhere in Bangladesh.

Further research is, therefore, necessary to reach a conclusion.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh to investigate regional adaptability and other performances;
2. The results are required to substantite further with different varieties of rapeseed and mustard.
3. It needs to conduct more experiments with K and Zn whether can regulate the morphological characters, yield and seed quality of rapeseed BARI Sarisha 15.

CHAPTER VII

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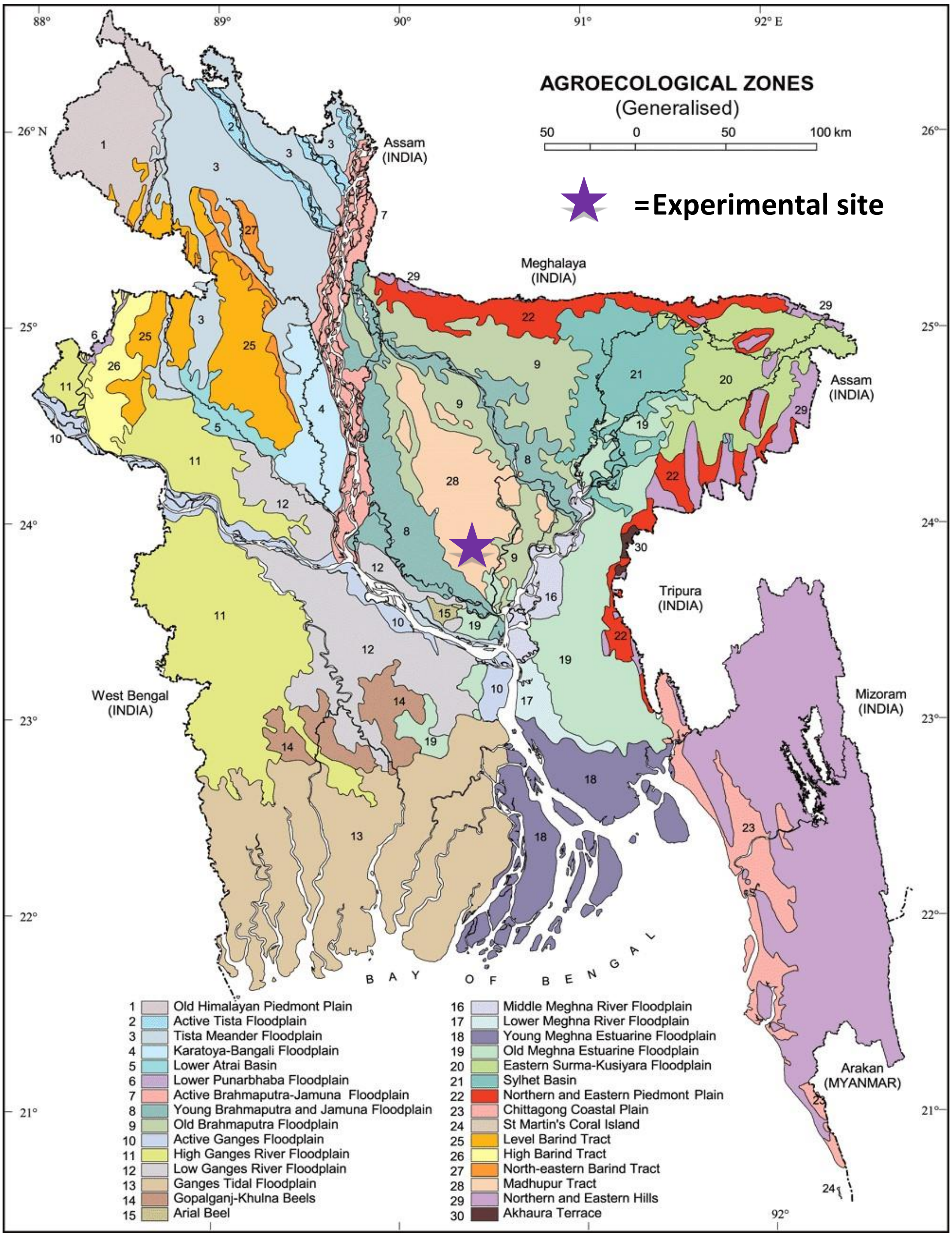
CHAPTER VIII

Appendices

Appendix I. Map showing the experimental site under study

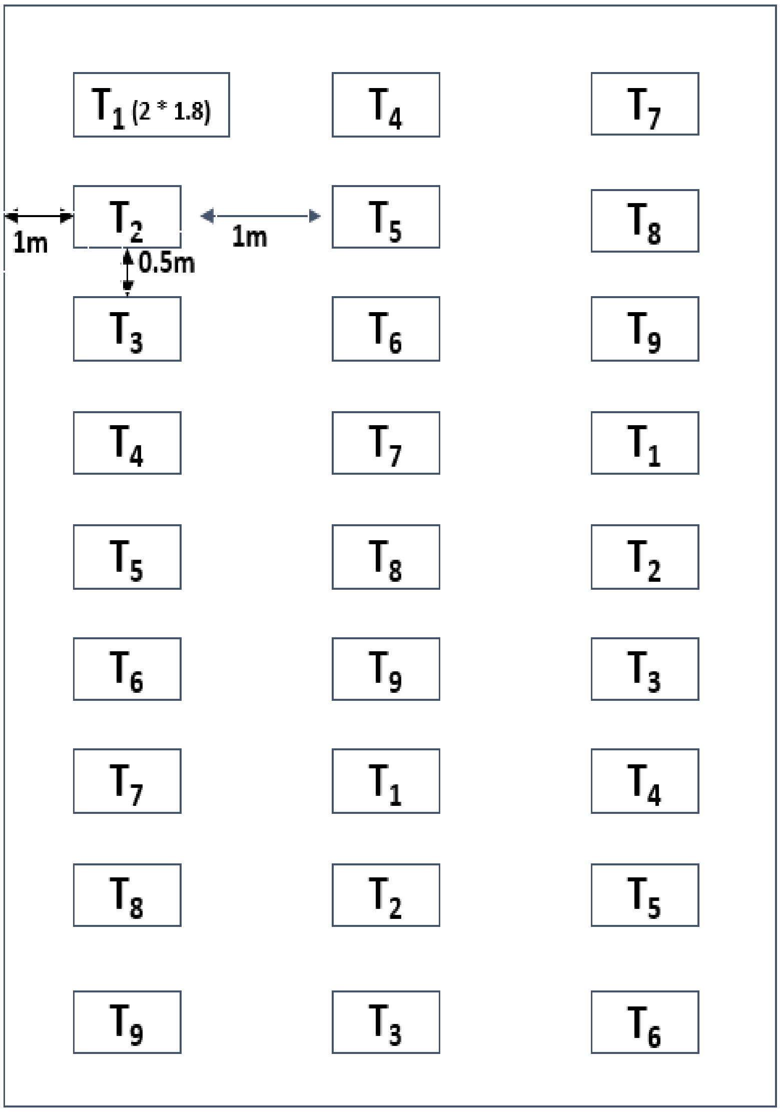


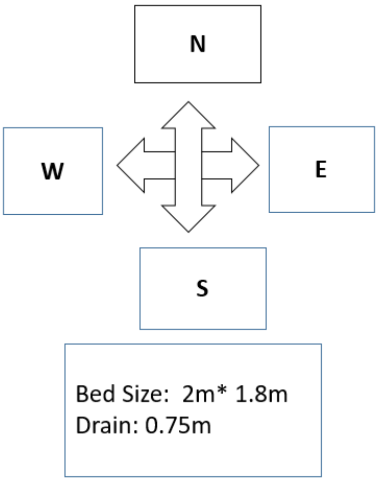
Appendix II. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	Percent
Sand	27.32
Silt	51.75
Clay	20.93
Textural class	Silty clay
Chemical characteristics	
Soil characters	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from October, 2020 to April, 2021

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2020	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	32.4	21.1	63	31





Appendix IV: Field layout of the experimental plot

Appendix V. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

Appendix VI. Monthly average air temperature, relative humidity, total rainfall and sun shine hours of the experimental site during November’20-February’21

Year	Month	Air Temperature (^0C)			Relative Humidity (%)	Total Rainfall (mm)	Sun Shine (hr)
		Max.	Min.	Mean			
2020	Nov.	29.2	20.5	24.85	67.0	9	7.3
	Dec.	26.4	17	21.7	60.0	9	7.4
2021	Jan.	26	15.3	20.65	53.0	10	7.6
	Feb.	29.8	17.4	23.6	45.0	25	7.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka-1

Appendix VII. Physiochemical characteristics of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	silty loam
pH	5.8
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Available P (µg/ g soil)	23.64
Exchangeable K (me/ 100 g soil)	0.60
Available S (µg/ g soil)	28.43
Available B (µg/ g soil)	0.05
Available Zn (µg/ g soil)	2.31

Source: Soil Resources Development Institute (SRDI), Dhaka-1207