Sudan University of Science and Technology

College of Graduate Studies

Genetic variability, and Stem borer resistance of some Maize (*Zea mays L.*) genotypes

التباين الوراثي ومقاومة حشره ثاقبات الساق في بعض الطرز الوراثيه للذرة الشامي

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A Thesis Submitted in Partial Fulfillment for the Requirements of Master Degree in Agriculture (Agronomy)

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April 2017

قال الله تعالي:

فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ ﴾

صدق الله العظيم

[سورة التوبة: 105]

Dedication

To my parents

My Wife, Daughters, Brothers and Sisters

Acknowledgements

Praise and thanks are due to Allah who has given me the patience till completing this study. I wish to express my deepest and sincere appreciation to my supervisors **Dr. Ahmed Ali** and **Dr. Mohammedain Babekir** for their patience, active guidance and encouragement during this study. Considerable thanks, to the Agro nectar Group for the professional support which, made it possible to achieve this work.

I would like to express my thanks to all members of the staff of the faculty of College of Agricultural Studies. Shambat. Finally I would like to express my sincere thanks and deepest gratitude to my family for their unlimited help.

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Abstract

The study was conducted in the experimental farm of the College of Agricultural Studies at Shambat and Gezira University at Madani .The objectives were to evaluate the performance of 17 maize genotypes resistant to stem borer. An experiment was conducted under irrigation in winter season (2014/2015). The experiment consisted of thirteen genotypes developed by Maize Research Program, Agricultural Research Corporation (ARC), and three lines developed at the National Institute for Promotion of Horticultural Exports University of Gezira, together with Mugtama-45 as the local check. The different genotypes were arranged in Randomized Complete Block Design (RCBD) with four replications. Growth and Yield parameters included (Days to 50% tasseling, plant height (cm), leaf area), yield (t/ ha) and its components (number of row per ear, kernel weight (g), grain yield (t/ha) were studied. All the studied trait showed non-significant differences between locations at 5% level among the 17 genotypes. Indicating the presence of genetic variability among the different genotypes Non-significant interaction between Genotype × seasons (G× S).Genotypes at Medani and Shambat sites showed significant differences for days to 50% tasseling. Genotypes at Medani and Shambat sites were significant differences at 1% for plant height. Non- significantly different at Medani and Shambat for leaf area. Highly broad sense heritability estimates (19% - 73%) were shown by the measured traits. Grain yield showed high and positive correlations number with rows per ear with kernel weight (=0.4) and total yield (=0.6). High grain yield 3.7 and 3.5 t/ha was recorded for the genotypes C407 and M2, respectively. However non- significant difference obtained for the cultivar Mugtama-45 used as control which recorded 3 t/ha. The genotypes resistant C402, C403, C404, C408, C412, M2, and M3 showed the best genotypes for stem borer infestation at the two sites with an infestation rate of less than 1.

خلاصة البحث

أجريت الدراسه بالمزرعه التجريبيه بكليه الدراسات الزراعية، شمبات وكلية الزراعه جامعه الجزيره ، مدني، هدفت الدراسة إلى تقييم 17 سلاله وراثيه مقاومه لثاقبات الساق. اجريت التجربه بالري شتاء موسم 2014/2015م. شملت الدراسة 13 طرز وراثية من الذرة الشاميه تم الحصول عليها من برنامج تطوير الذرة الشامية هيئه البحوث الزراعية و3 طرز من برنامج تطوير الذرة الشامية، معهد الصادرات البستانية ، جامعه الجزيرة بالإضافة إلى الصنف مجتمع 45 الذي استخدم كشاهد . استخدم تصميم القطاعات العشوائية الكاملة (RCBD) بأربعة مكررات. تم دراسه صفات النمو والانتاجيه والتي اشتملت علي (50% إزهار، طول النبات، مساحه عرض الورقة)، وصفة الإنتاجية (طن/ هكتار) ومكوناتها (عدد صفوف الحبوب في الكوز، وزن ال100 حبة، إنتاجية الحبوب (طن/ هكتار). كل الصفات التي درست اظهرت عدم وجود فروقات معنويه بين السلالات تحت مستوي معنوية 5 % في الموقعين . هذا يشير الي وجود تغير جيني بين 17 طرز وراثيه . لا توجد فروقات معنويه تفاعليه بين الطرز مع الموسم . الطرز بموقعي مدني وشمبات بها فروقات معنويه تحت مستوي 1% عند 50% من ايام الازهار . وكذلك عند طول النبات بها فروقات معنويه عند 1% . لا توجد فروقات معنويه بالموقعين عند مساحه الورقه . أظهرت الدراسة انه لا توجد فروقات معنوية بين السلالات الوراثية في كل الصفات التي درست تراوحت قيمة المكافئ الوراثي بالمعنى العريض بين 19-73% بالنسبة للصفات التي درست. أظهرت الدراسة أن صفة الإنتاجية(طن/ هكتار) ارتبطت ارتباطاً موجباً لعدد الصفوف مع وزن الحبة (0.4=) ومجمل الإنتاجية (0.6=) ووزن الحبة مع إنتاجية الحبوب (0.5 =) أعلى إنتاجية 3.7 و 3.5 طن/ هتكارسجلت في الطرز الوراثيةC407 و M2 علي التوالي. بينما تراوحت إنتاجية الطرزالأخرى بين 2.2إلى 3 طن/ هكتار.علماً بأنه لايوجد فرقاً معنوياً بينهما وبين الصنف القياسي مجتمع 45 والذي سجل إنتاجية بلغت 3 طن/ هكتار. أظهرت الدراسة أن االطرز C402 , C403 , C404 , C408 , C412 M2 , M2, أعطت اقل معدل إصابة 1 .

CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is the third most important food crop of the world, after wheat and rice, providing 15% of the protein, and19% of the calories for the developing countries. (Shakoor *et al.*,2007).United States is the largest consumer and producer of maize in the world it is estimated that the total world production around 980 million metric tons of maize every year from which 40% comes from United States, China 229 million metric tons, Brazil 77 million metric tons,south Africa 13 million metric tons. (Http: //farmdocdaily.illinois.edu. 2016), In Sudan, it ranks **4th**in importance as a cereal crop coming after sorghum, millets and wheat. It is grown mainly as feed crop (both grain and forage) and rarely as food crop. Due to the increased demand for animal products driven by the accelerated process of urbanization, an urgent need for maize has emerged in recent decades to meet the requirements of the growing poultry industry. Based on FAOSTAT (2011) the average production of maize per annum in the Sudan during the eighties (29000 ton) was doubled (59000 ton) during the 2000s. Imports of maize showed similar trend, rising from < 20000 ton during 1985-95 to > 40000 ton during the 2000s. If the above statistics are valid, the present Sudan requirement for grain corn could be estimated around 100000 ton, of which more than 40% is imported. (Maarouf *et al*., 2012), However, the crop plays a great role in food security for the people in Blue Nile and South Kordofan States, where the crop is grown by traditional farmers in small-holdings under rain-fed. Recently, some companies and individuals started to grow the crop at a large scale under irrigation (surface and pivot) or under rainfall in different parts in the country. (Abdel Rahman *et al*., 2012). The small cultivated area of maize at the irrigated schemes compared to other cereal crops in Sudan could be attributed to the sensitivity of maize to both drought and water logging, besides; maize is not largely grown as staple human food like sorghum, millet or wheat in the country (Abdel Rahman *et al*., 2012). The limited local use by users and low market price has also contributed to the less priority of maize production in Sudan agricultural development plans (Ali *et al*., 2009). Therefore, maize cultivation in the past and until recently was neglected by decision. The recently increased export opportunities for maize to other countries and the growing poultry and livestock industry inside the country, increased the demand for maize feed and forage (Ali *et al.,* 2009). Moreover, the possibility of blending maize with wheat for bread- making also increased the demand for maize in Sudan. Lack of improved seeds is one of the major problems hindering maize production in the Sudan. This may partially explain the low yield levels (below 1 ton/fed) reported for maize in the Sudan (Maarouf *et al*., 2012), Therefore, the total cultivated area of maize was increased from 17 thousand hectares in 1971 to about 37 thousand hectares in 2010 (Ahmed, 2007). Although the research work in maize over the past fifty years did not continue at all times, it succeeded to recommend the key management practices and release six high yielding open pollinated varieties and five exotic maize hybrids. However, the average grain yield of maize in Sudan (0.6 to 1.0 t /ha) was very low compared with that of the world (6 t/ha) FAO, (2007). The low yield of maize coupled with the current high local consumption resulted in the current big gap between maize production and the actual demand and therefore, large, quantities of maize should be imported to fill this gap in Sudan. Accordingly, the release of more maize hybrids for commercial use in Sudan is important and justified (Abdel Rahman *et al*., 2012). The production of maize in Sudan facing many constrains such as biotic factor, therefore, the stem borer infestation is considered as one of the limiting factors for growing of maize during winter season in central of the Sudan. Hence, the study of mode of resistant and genetic components of the stem borer resistant cultivars coupled with the high yielding and quality will help to cultivate maize during winter season and provide an alternative crop to be used in irrigated schemes, therefore the specific objective of this study were to:

1- Study the genetic variability.

2- Study of some maize genotypes resistant to stem borer.

3- Study correlation among some traits and path coefficient analysis for yield.

CHAPTER TWO

LITERATURE REVIEW

Maize is cultivated throughout the world and plays an important role in human and animal feeding. The demand is continuously increasing and cannot be satisfied without strong technological interventions (Shiferaw *et al.,* 2011). Maize is the most important cereal crop in sub-Saharan Africa (IITA, 2009) and Africa produced in 2012 more than 69 million tons of that crop (FAO, 2013). The maize yield character is influenced by several genes which also interact with various environmental conditions (Bocanski *et al.,* 2009). Thus, the yield has a multiplicative effect on the end product of many factors otherwise referred to as yield components, (Zeeshan *et al.,* 2013). These yield components are simply inherited with minimal environmental deviations, and hence selection based on them is more appropriate as opposed to the yield per se. (Nagabhushan *et al.,* 2011). The assessment of performance of parental lines based on the yield components could aid in the selection of superior parents for the production of better yielding hybrids (Bocanski *et al.,* 2009). This can successfully be achieved if the genetic parameters which govern inheritance of important agronomic traits are established. (Mahiboobsa *et al.,* 2012). In addition, the proper characterization of the physiological traits and their relationships with maize yield and yield components coupled with utilization of the revealed genetic variability could lead to improvement and broadening of the diversity of the maize gene pool. (Alake *et al.*, 2008; Al-Tabbal *et al.,* 2012).

2.1 Phenotypic variability

Variability in a population is of paramount importance for any successful breeding program, this is because selection of the desirable genotypes for certain traits will not be effective unless considerable amount of variation exists in the population many workers have reported a considerable amount of variability for different traits in maize. Crossa and Beck *et al.,* (1990) reported that one of the natural resources in America is the tremendous variability existing in maize. Malhotra and Khehran *et al.,* (1996) reported significant differences among genotypes for grain yield, cob length, 100-kernels weight and days to 50% silking(Adam *et al.,*2004) reported significant variation for grain yield per plant, days to 50% tasseling, plant height, ear height, 100-kernel weight, cob diameter, cob length, number of kernel rows per cob and grain yield per hectare and also reported a non-significant differences for number of cobs per plant, cob weight and 100-grain weight at one of the two locations.

2.2 Genotypic variability

The study of genetic variability is that of population genetics. It is the amount by which individuals in a population differ from one another due to their genes, rather than their environment. Variability is different from variation in that it is the potential to vary rather than the actual variation, (Yale *et al.,* 1995).The extent of the variability of a trait is likely to change rather than the actual variation (Ehrich *et al.,* 2005). Genetic variability in a population is very important because without variability, it becomes difficult for a population to adapt to environmental change creating a static population (Zaldivar *et al.,* 2003).

2.3 Important of pests and diseases

Maize stem borer, *Chilo partellus Swinhoe* (Lepidoptera: Pyralidae) is one of the major biotic constraints in successful maize and sorghum production worldwide (Pingali, 2001; James, 2003), particularly in Asia and Africa (Siddiqui and Marwaha, 1993; Arabjafari and Jalali, 2007).It has been reported to cause severe losses in maize crop throughout its geographical distribution. Yield losses of 24-75% have been reported by the attack of this pest alone (Kumar and Mihm, 1995, 1996; Kumar, 2002; khan 1983). (Farid *et al* .2007) Reported 10 – 50% damage by maize stem borer in Peshawar valley. Yield losses caused by stem borers in Africa could be as high as 80% for maize .Van den Berg, (2009)).

Insect Pests such as Stem borers, silkworms, grasshoppers, termites and weevils are the economically important insect pest of maize in Sudan and Nigeria

(Ojeniyi and Kayode *et al.,* 1993). These pests are grouped into the field pests. Although several diseases have been identified on maize in Sudan and Nigeria (Fujimoto *et al.*, 1993) reported only few of them significantly reduce maize yield. These are maize rust, maize streak, downy mildew, maize mottle/chlorotic stunt, leaf spot, stalk and ear rots. In order to make maize farming economically feasible, resistant lines were bred and made available to farmers in most of the major producing countries.

2.4 Heritability

Is a measure of the phenotypic variance attributable to genetic causes and has predictive function in plant breeding. It provides information on the extent to which a particular morphogenetic character can be transmitted to successive generations. Knowledge of heritability influences the choice of selection procedures used by the plant breeder to decide which selection methods would be most useful to improve the character, to predict gain from selection and to determine the relative importance of genetic effects (Waqar-Ul-Haq *et al.,* 2008; Laghari KA, *et al* .2010). The most important function of heritability in genetic studies of quantitative characters is its predictive role to indicate the reliability of phenotypic value as a guide to breeding value. (Falconer *et al*. 1996).

2.4 Correlation and Path Coefficient Analysis

Genetic improvement in traits of economic importance along with maintaining sufficient amount of variability is always the desired objective in maize breeding programs (Hallauer *et al* .1972). (Grzesiak *et al* .2001). Observed considerable genotypic variability among various maize genotypes for different traits. (Ihsan *et al.,* 2005).Also reported significant genetic differences for morphological parameter for maize genotypes this variability is a key to crop improvement.

Most breeders on programs depend on the direction of the association between yield and its components and other factors involved. As that agriculturally, path analysis used by breeders to assist in traits to improve crop yield. (Milligan *et al* .1990). (Mani *et al* .1999) suggested that a grain per row was the best direct contributor to grain yield/plant. Hence, maize breeders should give more importance to grains/row as selection criteria for yield improvement. (Gautam *et al*., (1999a).Found that grain yield was positively correlated with grain rows, 1000-grain weight, shelling percentage, plant height and ear height. The direct effects of plant height and ear height towards grain yield were small, as was that of days to silking indicating the possibility of developing high yielding plant types with short plant height, medium ear placement and early maturity.

(Arias *et al* .1999).Studied the cause effect relationship in maize for ear weight (the principal trait), plant and ear height, the ratio of ear height/plant height, number of kernels row and kernels per row on each ear. The direct and indirect effects on ear weight of plant and ear height and its ratio varied according to the evaluated progeny type. Among the other traits, number of kernel rows showed only a small positive indirect effect via ear diameter for all progeny types and populations, and the number of kernels per row showed high positive direct effect. (Khatun *et al* .1999) found that grain yield per plant was positively and significantly correlated with 1000-grain weight, number of kernels per ear and ear insertion height.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Experimental site

Experiments were conducted at two locations for one season (2014/2015), the first location at the Faculty of Agricultural at Medani on research farm (Latitude 14 - 24'N, Longitude 33 - 29' E, and 407m above sea level). The soil of which is a typical central clay plain which is characterized by its heavy cracking clay (clay content 58%*)*. It is also described as a calcareous alkaline soil, with a pH 8.3 and low organic matter content of 0.02% (Adam, 1998).

The second location at the farm of the College of Agricultural Studies Sudan University of Science and Technology, at Shambat (Khartoum North). (15 – 40'N, 32 - 33' E, elevation 380 m above sea level). The climate semi-arid, with allow relative humidity ranges between (14 – 27 %), during dry season, and (31 – 51 %) in wet season, maximum temperature is above 40^{c} in the summer is around 20^{c} in the winter season, and clay soil Celtic, PH 7.5 – 8.7.

3.2. Plant material

The plant material used in this study consisted of seventeen promising genotypes having sources of resistant to stem borer, thirteen of them developed by Maize Research Program, Agricultural Research Corporation (ARC), and three lines developed at the National Institute for Promotion of Horticultural Exports, University of Gezira, together with (**Mugtama-45**) as the local check,

3.3. Design of the experiment

The experiment was carried out using the Randomized Complete Block Design (RCBD), with four replications in the two locations in one season.

The code number C401 to C413 pedigree to Maize Research Program Agricultural Research Corporation (ARC), and code umber M1 to M3 pedigree to National Institute for Promotion of Horticultural Exports University of Gezira.

3.4 Land preparation

The land was prepared by disk plow, is harrowing and ridging. Planting was done on ridges of 80 cm apart, *25* cm within row spacing and a row length of three meters. Each genotype was assigned to one row. Three seeds were planted in each hole and then thinned to one plant per hole, one week after germination. Sowing dates were in the 3rd week of November. One dose of nitrogen (1N) in the form of urea (46% N) was applied once three weeks after emergence.

3.5 Data collected

Five randomly taken plants of each genotype from the middle of the row were used to measure the following traits:

3.5.1. Growth parameters

3.5.1.1. Average plant height

Plant height was measured in cm from the soil surface to the tip of the tassel

3.5.1.2. No of leaves per plant

Numbers of leaves per plant were counted at anthesis.

3.5.1.3. Days to 50% tassling

Days to 50% tassling referred to number of days from sowing until 50% of the plant there tassling in each row.

3.5.1.4 Leaf area

Leaf area was calculated by multiplying leaf length by leaf width with a factor 0.75. The unit was cm^2 and then this value was multiplied with the average number of leaves per plant to get the leaf area per plant.

3.5.2. Yield parameters

3.5.2.1. No of cobs per plant

Number of cobs per plant measured as the ratio of number of cobs over the plant stand.

3.5.2.2. No of grain per cob

Number of grains per cob was counted in the five plants.

3.5.2.3. Ear size

Ear size was taken after harvest in each row were counted randomly.

3.5.2.4. 100 kernel weight

The weight of 100 seeds was taken at random from the bulk of grains harvested in each row.

3.5.2.5. Grain yield per hectare (ton)

The total grain yield from all the 5 plants in the middle rows of each plot that were carefully harvested and threshed for full yield recovery was used to compute the grain yield (oven-dried at 13 – 14 % moisture content) in tons per hectare .

3.5.3. Evaluation for stem borer resistance:

The plant material intended to be used in this study will be evaluated for stem borer resistance using the 1-5 rating scale. Where:

1- Severely infested by stem borer in leaves and stem.
2- Moderate infestation in leaves (number of infested leaves).
3- Intermediate infestation in leaves.
4- Mild infestation in leaves.
5- No infestation symptoms.

3.6. Statistical analysis

Analysis of variance was carried out, with SAS version 9.1 (SAS Institute, 2004) for each season separately. Then, the combined analysis of variance, for the RCBD. Was done for the traits in which the mean squares of error were homogeneous.

3.7. Estimation of genetic parameters

Phenotypic and genotypic coefficients of variances, heritability in broad sense, genetic advance and genetic advance as percentage of mean were computed as mentioned below Genotypic and phenotypic variances were computed using formulas:

$\sigma^2 G = \frac{MSg\_MSe}{r}$

$\sigma^2 e$ = **M S e**

$\sigma^2 P = \sigma^2 G + \sigma^2 e$

$- \frac{MSg\_MSc}{r}$ **+ M S e**

Where:

a^2G = Genotypic variance

a^2P = Phenotypic variance

a^2 e = Environmental variance

MS g Mean squares of genotype

MS e = Mean squares of Error

r = Number of replications

3.8. Heritability (h^2B)

Heritability (broad sense) values were estimated by the formula suggested by (Johnson et *al* .1955).

$h^2B = \frac{\sigma^2 G}{\sigma^2 P}$ X100

Where:

a^2g = Genotypic variance

a^2p = Phenotypic variance

The heritability percentage was categorized as low, moderate, and high as suggested by Robinson et al. (1949) as follows.

0 - 30%: Low

30 - 60 %: Moderate

60% and above: High

3.9. Genotypic and phenotypic coefficients of variation

Genotypic and phenotypic coefficients of variation were computed according to Burton and De Vane (1953).

Genotypic coefficient of variation (GCV) >100 =

Phenotypic coefficient of variation (PCV) < 10 C =

Where:

a^2g = Genotypic variance

a^2p = Phenotypic variance and;

X = General mean of trait

The PCV and GCV values are ranked as low, medium and high as suggested by (Sivasubramanian and Menon, 1973) and are mentioned below:

0-10%-Low

10-20% - Moderate

>20% - High

Genetic advance (GA)

Genetic advance for each trait was calculated by using the formula (Allard, 1960).

a^2 G

GA=xICp

ci^2p

Where:

a^2G = Genotypic variance

a^2P = Phenotypic variance

K = Selection differential which has value of 2.06 at 5% selection intensity.

Phenotypic standard deviation

Genetic Advance as percentage of mean (GA %)

GA%=

Where: ap x

a^2 G Genotypic variance

aP = Phenotypic standard deviation.

K = Selection differential, which has the value of 2.06 at 5% selection Intensity.

X= the general mean of trait

Genetic advance as percent of mean was classified as low, moderate and high

(Johnson et al., 1955) and values are given below:

0-10% - Low

10-20% - Moderate

20% and above — High

Phenotypic correlation

Phenotypic correlation coefficients between pairs of different traits were determined, according to the formula suggested by Miller *et al.*, (1958).

Covariance analysis between the eight traits under study was carried out, following the same procedure as in analysis of variance. Estimates of genotypic and phenotypic covariance were used to compute the genotypic and phenotypic correlation coefficients between pairs of the eight traits done as follows:

(Genotypic correlation of coefficient)

Co; xvg

(C 2g (0.2 9Y)

Where:

Cl gxy is the genotypic covariance between two pairs x and y

G^2gx and c^2gy are the genotypic variance for traits x and y

(Phenotypic correlation of coefficient) rp = Y P

Q^2r (2 iky)

Where:

CS phxy is the phenotypic covariance between two pairs, x and y O^2ph x and a^2phy are the phenotypic variance for traits x and y

Path coefficient analysis

Path coefficient analysis was carried out, using the procedure suggested by (Dewey and Lu, 1959), for;

(a) Partitioning of the genotypic correlation between grain yield and five traits; and

(b) b) Determine the direct and indirect effects of the different traits on grain yield.

Traits involved in the model were

1. Fodder yield. (Xl)
2. 100-Seed weight (X2)
3. Plant height (X3)
4. Days to maturity (X4)
5. Number of pods/plant (X5)
6. Grain yield (X6)

The path coefficients (direct effect) of the five traits, involved in the model, on grain yield (X6) were obtained by the following simultaneous equations, based on the data of the first season:

r16=p16+r12p26+r13 p36+r14p46+r15 p56 (2)

r26=rl2pl6+p26+r23p36+r24p46+r25p56 (3)

r36=r13 pl6+r23p26+p36+r34p46+r35p56 (4)

r46r14p16+r24p26+r34p36+p46+r45 p56 (5)

r56 r15 p16 + r25 p26 + r35 p35 + r45p46 + p56 (6)

Where:

r16, r26, r36, r46, and r56 = Genotypic correlation coefficients of the five traits involved in the model with grain yield (X6), respectively.

r 12, r13 , r14 , r15 , r23 , r24 , r25 , r34, r35 , andr45 Genotypic correlation of the possible pair-wise combinations of the five traits.

P16, p26, p36, p46, and p56 path coefficients (direct effects) of the five traits on grain yield (X6).

3.10. Residual effect

The residual effect was determined, according to Singh and Chaudhary (1979), by substituting the estimated path coefficient and the genotypic correlation coefficients in the following equation:

1= Px62 + P162 + P262 + P362 + P462 + P562 + P16r16 + P26r26 + P36r36 + P46r46+P56r56

Where:

Px6 = path coefficients of x variables, excluded traits, on grain yield.

CHAPTER FOUR

RESULTS AND DISCUSSION

Seventeen genotypes were evaluated for agronomic and yield characteristics, and resistance to stem borer in one season at two locations (2014 /2015). Ten characters, including vegetative and yield parameters were studied .Combined analysis showed non- significant differences between locations and significant differences among the 17 maize genotypes for most traits studied. Indicating the presence of genetic variability among the different genotypes which is expected since the genotypes were bred for different goals. Non-significant interaction between Genotype × Season (G× S) for all characters studied was shown (Table 4.1.) Variability among these genotypes for all studied parameters could be exploited in hybrid breeding.

4.1. Growth parameters

4.1.1 Days to 50% tasseling

Differences among genotypes at Medani and Shambat sites were significant at 1% for days to 50% tasseling. M2 was the earliest to anthesis (40 days) followed by C401 (41 days) and M1 (42 days), as presented in (Table 4.2 and 4.3) Mujtama 45 was the latest with 57 days to 50% tasseling. Generally, earliness in maize is so important for avoidance of late season infestation of stem bore. (Mohammdein *et al.,* 2012).

4.1.2 Plant height

Differences among genotypes at Medani and Shambat sites were significant at 1%. The overall grand mean of genotypes with respect to plant height was 188.8 cm at Medani site, 189.5 cm at Shambat site, (Table 4.2 and 4.3). The genotype Mujtama45 was the tallest genotype with 196.2 cm length. There was no significant difference among C404 (196 cm), C 409 (195.5 cm), C405 (194.6 cm), C401 (194.6 cm), C406 (194 cm), C411 (193.6 cm), C407 (193.6 cm) and C402 (193.3 cm). The genotype M3 was the shortest with plant height of 172 cm at Medani site and C411 at Shambat site. (Molhotra and Khehra *et al.,* 1996) studied genotype variation in the indigenous germplasm of maize and they reported a wide range of the genetic variability in plant height. However, trends in breeding are to develop cultivars that are dwarf to moderate height to avoid lodging of the crop, which adversely affect yield. Nitrogen rate was reported to affect plant height significantly (Abdel Rahman *et al.,* 2008). The genotype C404 and M3 exhibited the highest plant height 196cm and 200.3cm Medani and Shambat, respectively, and therefore they recommended to be used in forage production. Yet the high plant subjected to stalk lodging in maize. Kang *et al.,* (1999) reported that lodging may account for annual yield losses of 5- 25% in this crop.

4.1.3 Leaf area

The genotypes C411 and M2 gave the largest leaf area of 590 cm^2 and 574.3 cm^2 at Medani and Shambat, respectively, and the genotypes M3 and C403 gave the lowest leaf area of 314 cm^2 and 375 cm^2 at Medani and Shambat, respectively. Generally, increase of dry matter production is strongly dependent on leaf area as well as photosynthetic rate and eventually reflected in grain yield (Tadashi and Theodore *et al.,* 1999). Nyuetta and Cross *et al.,* (1997) reported that maize genotypes with high leaf number tend to produce longer leaves and ears which improving grain yield. It might be due to the fact that nitrogen plays very important role in the growth and development of the plant since nitrogen is the main constituent of protein and hence resulted in vigorous growth and increased leaf area and leaf area index (Rasheed *et al.,* 2003). In contrast, differences among genotypes for all studied traits were non- significantly different at Medani and Shambat sites. (Table 4.2 and 4.3.)

Table 4.1Coefficient of variation, standard error and probability of seasonal differences of all parameters Coefficient of variation, standard error and probability of seasonal differences of all parameters.

Characters	**Combined analysis**		**Effect of location (prob.)**
	CV%	**SE**	
Days to anthesis	13.4	1.63	0.35
Days-to-maturity	9.34	3.36	0.16
Plant height	7.54	2.2	0.34
Ear per plant	22.4	2.1	0.081
Kernel grain weight	8.3	5.02	0.054
Kernel weight	9.4	1.19	0.04
Grain yield per plant	16.53	2.135	0.19
Number of leaves per plant	6.31	9.14	0.06
Leaf area (cm)	24.2	2.13	0.021
Stem borer infestation	42.13	2.41	0.21

Table 4.2. Days to 50% tasseling, plant height, Leaf area. Medani location season, 2014 - 2015

Genotypes Medani	**Days to 50% tasseling**		**Plant height (cm)**		**Leaf area**	
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
C401	41j	15	194.6a	5	410.3b	8
C402	53de	7	193.3a	9	410b	9
C403	63ef	8	180.6de	16	369.6b	14
C404	54cd	5	196a	2	440.3ab	7
C405	53ef	9	194.6a	4	397b	10
C406	52ef	10	194a	6	396.6b	11
C407	51gf	12	193.6a	8	460.3ab	4
C408	55abc	3	188.6b	10	446ab	6
C409	54bcd	4	195.6a	3	447.6ab	5
C410	54de	6	188.3cb	11	395.6b	12
C411	52gf	11	193.6a	7	590a	1
C412	51g	13	181de	15	394.3b	13
C413	43i	14	184.3cd	12	367.3b	15
M1	42ij	15	184.3cd	13	470.6ab	3
M2	40h	16	178e	16	574.3a	2
M3	56ab	2	172f	17	314b	16
Mu 45	57a	1	196.2 a	1	328b	17
Mean	51		188.8		424.2	
CV	1.6		1.24		19.7	
F value	103**		30**		2.3*	

Mean followed by the same letter(s) in each column are non-significantly different at P=0.05.

Table 4.3. Days to 50% tasseling. Plant height, Leaf area. Shambat location season, 2014-2015

Genotypes shambat	Days to 50% tasseling		Plant height (cm)		Leaf area	
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
C401	46a	17	188.3ab	10	444a	7
C402	50a	11	191.3ab	6	409.3a	11
C403	50a	8	189.3ab	8	375a	17
C404	46a	16	185.3ab	13	435.6a	10
C405	52a	4	188ab	11	436a	8
C406	54a	2	181.6ab	16	380a	16
C407	50a	12	183ab	15	465a	1
C408	52a	3	187ab	12	461.3a	3
C409	50a	9	202a	1	399a	15
C410	50a	10	189.6ab	7	403a	14
C411	51a	6	172b	17	452a	5
C412	49a	13	189ab	9	435.6a	9
C413	51a	7	195ab	4	408.3a	12
M1	48a	15	200.6a	2	445.6a	6
M2	49a	14	184ab	14	453.6a	4
M3	52a	5	200.3a	3	465a	2
Muja 45	55a	1	195ab	5	406.3a	13
Mean	50		189.5		427.9	
CV	11.4		5.5		16.3	
F value	0.51		1.58		0.52	

Mean followed by the same letter(s) in each column are non-significantly different at P=0.05.

4.2. Yield and yield components

4.2.1 Number of rows per ear

All genotypes differed significantly at 5% with respect to number of rows /ear in the combined analysis. (Table 4.4 and 4.5.) The mean number of rows /ear ranged between 11.6 and 12.The genotypes M1 and M3 gave the highest number of rows per ear 14 and 13 at Medani site, and C401 and C412 gave the highest number of rows per ear 13 at Shambat site .The genotypes C405 and C409 gave the lowest number of rows per ear 10 and 11, respectively at Medani and Shambat sites, respectively .The genotypes M1and C401 they had higher numbers of rows/ear compared to Mujtama 45, with gave12 rows per ear. This indicates that the maize genotypes studied differed with respect to the position of the first cob on the plant. (Silvestro *et al.*, 2003) reported high significant difference among six land races of maize in Sudan for ear height. Total numbers of rows /ear is undesirable since it increased susceptibility to stem loading particularly in high yielding cultivars with more weighty ears that may not stand heavy winds. (Esechiev *et al.*, 2004) studied 11 maize varieties and they reported highly significant negative correlation of loading with grain yield.

4.2.2 100 – kernel weight

This component is an important selection index for yield. The combined analysis of variance revealed significant difference among the 17 genotypes (P> 0.01).The mean of 100 kernel weights of the genotypes ranged between 18.9g and 19.2g. The genotypes M2 and C407 gave the highest kernel weight of 21.2g and 20.1g, respectively. While the genotypes C401 and C410 had the lowest kernel weight of 17g and 18.1g, respectively. All of the genotypes were non-significant different from the check cultivar Mujtama45 (Table 4.4 and 4.5). Generally, variation among the genotypes with respect to kernel weight was expected since the genotype were bred for different goals e.g. some genotype bred for improving quality of protein while others were bred for stem borer resistant. Many workers reported significant different among maize genotypes for 100 kernel weight (Silvestreo *et al.*, 2003 and Ahmed *et al.*, 2007).It was concluded that the kernel size is influenced by the grain filling duration (Jorge1995),rate of phosphorus and nitrogen fertilizers application (Abdel Rahman *et al.,* 2008). Therefore, application of nitrogen to these genotypes may affected kernel weight and yield as general.

4.2.3 Grain yield (ton/ha)

Grain yield is the primary trait targeted for the genetic improvement. The combined analysis of variance is presented, Table 4.4 and 4.5. Indicates highly significant differences among the 17 genotypes (P> 0.01) with respect to grain yield (t/ha). The mean grain yield of genotypes ranged between 2.7 and 3.4 at Medani and Shambat site, respectively. The Genotypes C407 and M2 gave the highest grain yield 3.7 and 3.6 at Medani and Shambat site, respectively , while the genotypes C404, C402 gave the lowest grain yield of 2.2 and 3.1 t/ha, respectively. The latter two genotypes were considered as normal maize genotypes. Regarding grain yield per plant, were non- significantly different from the check cultivar Mujtama 45. (Table 4.4 and 4.5.) Stability of grain yield of a cultivar over various environments is the most desirable property of a genotype to be released as a cultivar for wide cultivation .The non-significant G× S effect in this study supported stability of the high yielding genotypes. Similarly, (Ahmed *et al.,* 2007) reported significant difference among 24 maize genotypes tested at the Gezira Research Station. Results were in a line with. (Abdel Rahaman *et al.,* 2008) who reported mean grain yield of 2.9, 3.7, 3.1 t/ha in autumn sowing for the cultivars Hudeiba-1, Hudeiba -2, Mujtama 45. Since the genotypes C407 and M2 scored 3.8 and 3.6 ton/ha in winter it were considered as a promising genotypes and was suggested to be grown over different seasons and different locations to test for genetic stability.

Table 4. 4 Number of row per ear, kernel Weight (g), grain yield (kg/ha) Medani location season, 2014 - 2015.

Genotypes Medani	Number of row/ear		Kernel weight (g)		Grain yield (kg/ha)	
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
C401	11.3c	9	16.8i	17	2406.6h	13
C402	11.3c	12	20.9a	2	2553.3f	12
C403	10.6c	15	19.2d	7	2544.3f	8
C404	11.6c	6	19.1d	8	2260j	17
C405	10.6c	17	18ef	12	2539f	11
C406	11.3c	14	17.2hi	15	2553.3f	7
C407	11.3c	11	17.2hi	16	2544.3f	9
C408	10.6c	16	18.3e	11	2842.3d	5
C409	11.3c	13	19.7c	6	2273.3j	15
C410	11.3c	10	17.4gh	14	2544.3f	10
C411	11.3c	7	18.3e	10	2337.6j	14
C412	11.3c	5	17.7gf	13	2633.3e	6
C413	12bc	4	19.1e	9	2271j	16
M1	14a	1	20.3b	5	3357.6b	2
M2	11.3c	8	21.2a	1	3584.6a	1
M3	13ab	2	20.4b	4	3347b	3
Mu 45	12bc	3	20.9a	3	2933.3c	4
Mean	11.6		18.9		2673.8	
CV	7.5		1.4		5	
F value	2.9**		89.6**		24.6**	

Mean followed by the same letter(s) in each column are non-significantly different at P=0.05.

Table 4. 5.Number of row per ear, kernel Weight (g), grain yield (kg/ha Shambat location season, 2014 - 2015.

Genotypes shambat	Number of row/ear		Kernel weight (g)		Grain yield (kg/ha)	
	Mean	Rank	Mean	Rank	Mean	Rank
C401	13a	1	19.8a	5	3575a	4
C402	12a	12	19.4a	8	3108.3	17
C403	12a	13	18.8z	15	3361a	10
C404	13a	6	19.4a	11	3355.7a	11
C405	12a	11	18.4a	16	3325a	12
C406	12a	14	19.3a	12	3486a	6
C407	13a	5	20.1a	1	3794.3a	1
C408	13a	4	19.1a	14	3691.7a	2
C409	11a	17	19.4a	10	3152.7a	15
C410	12a	16	18.1a	17	3208a	13
C411	12a	9	19.5a	6	3444.3a	8
C412	13a	2	19.5a	7	3447.3a	7
C413	12a	15	20.1a	3	3208.3a	14
M1	12a	8	19.1a	13	3533.3a	5
M2	13a	3	19.4a	9	3633.3a	3
M3	12a	10	20a	4	3411a	9
Muja 45	12a	7	20.1a	2	3108.3a	16
Mean	12		19.3		3404.8	
CV	8.3		7.4		16.3	
F value	0.64		0.48		0.39	

Mean followed by the same letter(s) in each column are non-significantly different at P=0.05.

4.3. Stem borer infestation

The most important species of stem borers are the spotted stem borer *Chilo partellus* (Swinhoe), found in the warmer and lower areas, and *Busseola fusca Fuller*, found in the cooler and higher altitudes (Mulaa, 1995). A third, less important species is *Sesamia calamistis.* Hampson, found at elevations of up to 2600 m. The feeding activity of the caterpillars inside the stems causes stunted plant growth, sterile or poorly developed ear heads. Plants may dry and die if the infestation is severe (CAB, 2002) .In this study, C402, C403, C404, C408, C412 and M2 were the best genotypes resistant for stem borer infestation at Medani site with an infestation rate of less than 1(Fig 1. A).The genotypes C409, C413, M1 and M3 scored infestation rate less than 2. Whereas, C401, C405, C410 scored an infestation rate of approximate 5. The commercial variety Mujtama45 gave an infestation rate of less than 3 (Fig 1. A). In Shamabat site, C412, M3 and Mujtama45 scored an infestation rate of 1 (Fig.1.B).The promising genotype at Medani M2 gave an infestation rate of 3 at this site. The same trend of infestation was given for C401, C405, and C410 (Fig 1 A).Combined results showed that the genotypes C402, C403, C404, C408, C412, M2, M3, and Mujtama45 were the best genotypes in the two sites (Fig 1 A and 1.B.). These results reflect the effect of stem borer, genotypes and the environment conditions and their interactions. The damage caused by stem borer in maize was reported by many researchers (Ahmad and Akhtar, 1979; De Groote, 2002; and Ouma *et al*., 2010). These results confirm the higher ability of these genotypes to tolerate and/or to resist stem borer infestation. The tolerance and/or resistance to stem borer coupled with yield superiority of some maize genotypes was reported by (Awan and Abdul Khaliq 2003; Mugo *et al* 2006; Ouma *et al* 2010). They were recommended to be examined for resistance to the two species stem borer species *Chilo partellus (*spotted stem borer*)* and *Sesamia cretica (*pink stem borer*)* under confined and field conditions in separate experiments.

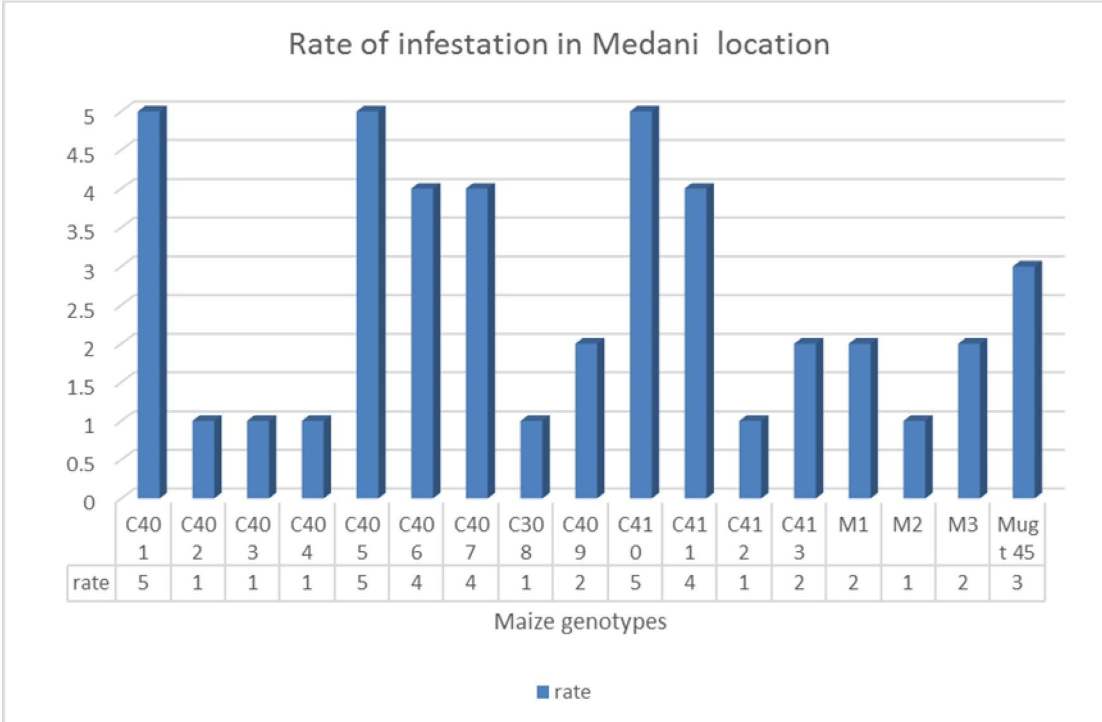

Fig.4. 1.A. The infestation rate of stem borer among seventeen maize genotypes evaluated, A at Medani location and B Shambat location winter season 2014/2015

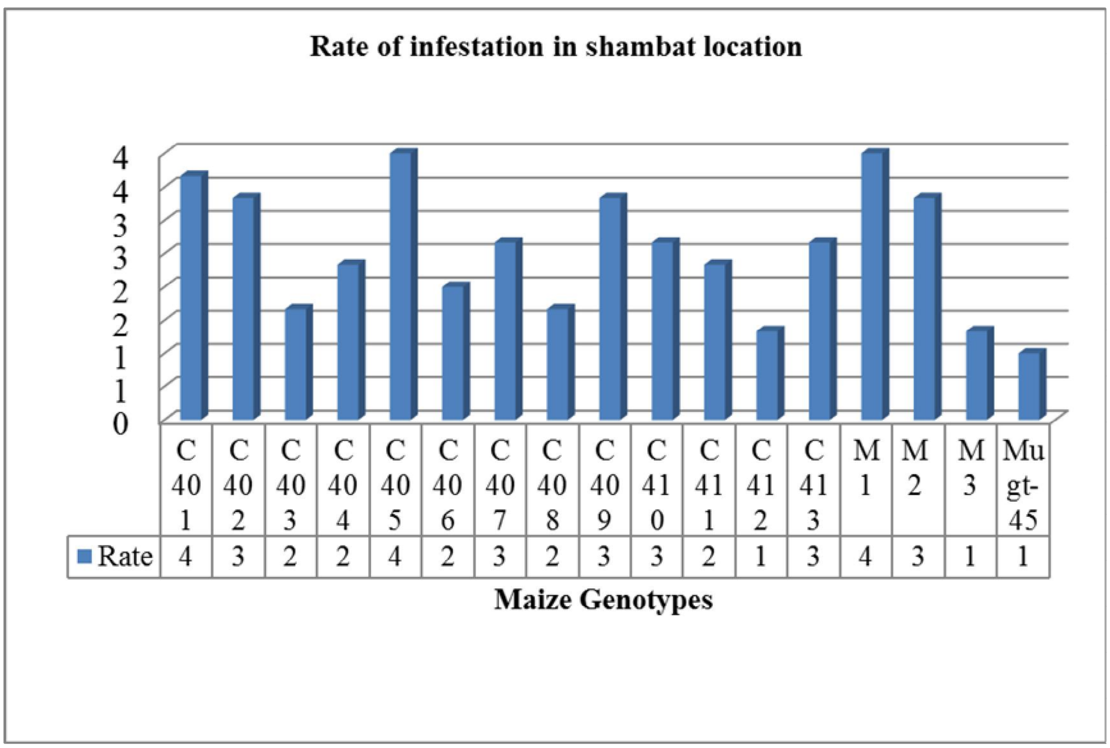

Fig.4.1.B.The infestation rate of stem borer among seventeen maize genotypes evaluated, at Shambat location winter season 2014/2015

4.3.1 Inter-relationship among agronomical and yield traits

Information about association among traits is important to determine which ones that can be used as selection criteria for more effective selection programs. For a trait to be useful in yield improvement, it must show strong relationship with grain yield and should be genetically heritable. Days to maturity showed significant and negative correlation with number of rows per ear, leaf area (cm) and total grain yield (ton/ha). Plant height showed negative and significant correlation with kernel weight and total grain yield (Table 4.6.).Whereas, significant and highly positive correlations were found for number of rows per ear with kernel weight (=0.4) and total yield (=0.6) and for kernel weight with grain yield (=0.5).The present findings were in conformity with those of (Salih, 2005) who studied genetic variability of maize and reported positive correlation between number of kernels per cob with grain yield (kg/ha) at 60 days (r= 0.6) and (Siddig, 1996) who reported that grain yield kg/ha was highly significant and positively correlated with 100-kernel weight, number of kernel rows and number of cob per plant. The path analysis among seventeen maize genotypes evaluated in their two locations Medani and Shambat is given in (Table 4.7.) from the obtained results the partition of correlation to direct and indirect effects among the studied genotypes showed higher direct effect was obtained by number of kernel per row (0.280) .The lower direct effect was given by leaf area (0.086).This results were in agreement with (Mani *et al.*, 1999)who suggested the grain per row was the best direct contributor to grain yield/plant. On the other hand, the indirect effect was recorded by having (0.158) number of row per ear followed by kernel weight (0.1043) with the lower indirect effects obtained by leaf area (0.142).

Table (4.6). Interrelationships between seventeen maize genotypes evaluated in Medani and Shambat combined season, 2014 - 2015

	DT	PH	NRE	LA	KW	GY
DT	**1**	0.1301 ns	-0.36148**	-0.25626**	-0.03908 ns	-0.33693**
PH	0.1301 ns	**1**	-0.1451*	0.04599 ns	-0.25834**	-0.27005**
NRE	-0.36148**	-0.14519 ns	**1**	0.16456*	0.37208**	0.62179**
LA	-0.25626**	0.04599 ns	0.16456*	**1**	0.10873 ns	0.21711*
KW	-0.03908 ns	-0.25834**	0.37208**	0.10873 ns	**1**	0.48959**
GY	-0.33693**	-0.27005**	0.62179**	0.21711*	0.48959**	**1**

** Highly significant (1% level); * Significant (5% level); ns non significant

Note: DT= Day to maturity, PH=Plant height, NRE=Number of rows per ear, LA= leaf area, KW =100 kernel weight, GY= Grain yield

Table (4.7). the path analysis among seventeen maize genotypes evaluated in two locations Medani a 2014 -2015.

	DT	PH	NRE	LA	KW	GY
DT	-0.12936	-0.01575	-0.15861	-0.02225	-0.01096	-0.
PH	-0.01683	-0.12102	-0.06371	0.003993	-0.07248	-0.
NRE	0.046763	0.017571	0.438775	0.014286	0.104395	0.
LA	0.033151	-0.00557	0.072205	0.086814	0.030506	0.
KW	0.005056	0.031265	0.163259	0.009439	0.28057	0.

Note: DT= Day to maturity, PH= Plant height, NRE= Number of rows per ear, LA=Leaf area, KW=100 kernel weight.

4.3.2. Heritability of traits

High broad sense heritability ($h^2_{B)}$estimates were given by number of kernel rows per cob (73%), number of leaves per plant (67%) and grain yield per plant (56%), as presented in (Table 4.7) .Whereas, other traits showed moderate to low heritability estimates such as 100 seed weight (32%), plant height (28%), days to maturity (23%), leaf area in cm (21%) and days to anthesis (19%). The heritability measures the value of selection for a particular trait in various types of progenies, (Al-Tabbal *et al.*, 2012; Lule *et al.*, 2012). Heritability provides a better estimate of the breeding value (Allard *et al*, (1999). High value of heritability has been reported by (Chen *et al.*, 1996). These results were comparable with those by (Smith *et al.*, 1998) .Who reported high brood sense heritability for plant height and in this study the plant height showed a moderate (28%), and (Nawar *et al.*,1997) for grain yield per plant. Silvestro *et al.*, (2003) who reported high estimates of broad sense heritability of other traits such as plant height, number rows per kernel unlike those found in this study for grain yield per plant. High heritability estimates for maize grain yield have been reported by (Kashiani *et al.*, 2010). High broad heritability for days to silking, plant height and number of grains ear was showed by (Najeeb *et al.*, 2009). However, that result is in agreement with those obtained.

Table 4.8. Broad sense heritability (h^2B) estimates of the some traits.

Character	**G x S Interaction**	**h^2B (%)**
Days to 50% anthesis	0.79 ^{ns}	19
Days to maturity	0.83 ^{ns}	23
Plant height	0.91 ^{ns}	28
No of leaves per plant	0.61 ^{ns}	67
Leaf area in cm	0.87 ^{ns}	21
100 seed wt.	0.65 ^{ns}	32
No of kernel rows per cob	0.29 ^{ns}	73
Grain yield per plant	0.103 ^{ns}	56

Where:

^{ns} = no- significant at 5%.

Conclusions and Recommendations

Conclusions

- The studied germplasm showed high variability estimates for most of the studied traits including stem borer resistance.
- The locally selected genotypes exhibited good agronomic and yield performance in addition to stem borer resistance compared to the introduced genotypes.
- Significant and highly positive correlations were found for number of rows per ear with kernel weight (=0.4) and total yield (=0.6) and for kernel weight with grain yield (=0.5).
- High broad sense heritability (h^2_{B}) estimates were given by number of kernel rows per cob (73%), number of leaves per plant (67%) and grain yield per plant (56%),
- **Recommendation**
- To establish dialogic crossing program to study general and specific combining ability looking for selecting superior lines to be used in hybrid seed production.
- To evaluate the studied germplasm for resistance to either or both species of stem borer *Chilo partellus* and *Sesamia cretica*.

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