VARIATION IN AGRONOMICAL TRAITS AMONG HERBICIDE TOLERANT M₃ AND M₄ MAIZE LINES

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ABSTRACT

This study was conducted to assess variation in agronomical traits among 39 herbicide tolerant M_3 and 37 M_4 maize lines during March to July 2015 and September 2015 to January 2016 respectively. The experimental design was randomized complete block in triplicates. Data were taken on plant height, ear diameter, hundred seed weight, ear length, grains row^{-1} and ear^{-1}, total ears plant^{-1}, yield plant^{-1}, ear height and herbicide tolerance. Data were analyzed using Genstat 14th edition at 5% level of significance. The results indicated significant ($p<0.05$) variations among M_3 and M_4 for all traits except rows ear^{-1} and total ears plant^{-1}. The highest yielding M_3 and M_4 lines were 520-58 and 520-38_3 recording 116.2g plant^{-1} and 151.1g plant^{-1} respectively but yields were lower than check varieties (165.3g)and (183.5g) respectively. The most herbicide tolerant M_3 and M_4 line were 513-12 and 520-38_3 taking 25 days and 28.5 days to ultimate death respectively. Grain yield plant^{-1} correlated significantly and positively with most traits in M_3 while positive and significant correlation with 100 seed weight, grains row^{-1} and total ears plant^{-1} in M_4. Overall, results indicated that induced mutation could serve as a good source of variation for use in plant breeding.

Keywords: Maize, *Zea mays L.*, mutation breeding, correlation, agronomical characterization, variations

1.0 INTRODUCTION

Maize (*Zea mays L.*) is the third most important grain crop in the world, after wheat and rice. In Kenya, maize is the most important food crop. In 2015, the crop was grown on an estimated 1.6 million hectares and production was 2.8 million metric tons giving a national mean yield of 1.7 metric tons per hectare (FAOSTAT, 2014). Maize consumption in the same period stood at 3.750 million metric tons (Gitonga, 2015) thus outstripping the grain supplies. The extra demand had to be provided through importation.

Maize in Kenya is produced for various uses, such as food human, animal feed and fodder for poultry and livestock, alcoholic drinks, production of alcoholic and non-alcoholic drinks. The grains are also used in the manufacture of corn oil and as an income generating venture for farmers (Bekric and Radosavljevic, 2008; Aisha et al., 2015). Moreover, the grains are important in human nutrition in that its average daily consumption in Kenya contains an average food intake of 1,010 Kcal/person/day (Mohajan, 2014), which is 40% of the recommended daily intake for adults, and 28 grams of protein, which is 62% of adults' recommended daily intake (Sehmi, 1993). Despite its importance as a principal food crop in the country, average yields of maize are $1–1.7$ t ha^{-1} against the global average of 4.9 t ha^{-1}, about a third of the world average (Gianessi, 2014).

In feeding several millions people in Kenya, increased production of high yielding quality maize is required to feed the rapidly growing population. Plant breeders can utilize the breeding technologies to increase yields by focusing on traits of interest to improve phenotypic and genotypic variability necessary to increase the available genetic diversity in breeding germplasm (Tester and Langridge, 2010). Grain yield and herbicide tolerance improvement could be attained by indirect selection of morphological and physiological attributes such as short anthesis-silking interval in maize, plant and ear height, rapid maturity, herbicide tolerance days etc. (Awasthy et al., 2014). Mutation breeding involves development appropriate populations for screening and selecting few mutants with desired traits (Liang and Phillips, 2011) enhancing food security.

Agro-morphological variability among various genotypes is key to crop improvement (Grzesiak, 2001)). In maize, studies have been conducted in various parts of the world to determine agro-morphological variability (Ahmad et al., 2011; Charles et al., 2013 and Yadav and Indra, 2010) among maize genotypes. Results from those studies revealed that plant height, cob length, ear diameter, 100- seed weight, number of kernels row^{-1}, number of grains ear^{-1}, ear height and grain yield plant^{-1} were significantly different among the test genotypes (P<0.05). The most important yield related traits were number of kernel row^{-1} followed by cob length and 100- seed weight. Further, Kumar et al (2011) reported that yield per plant was negatively correlated with days to 50% tasseling and 50% silking. Studies conducted in Kenya indicate that significant differences exist for all traits studied thereby revealing the diversity of the maize genotypes and grain yield was positively and strongly correlated with ear height and plant height (Nzuve et al., 2014; Charles et al., 2013). To our knowledge, no studies have been conducted in Kenya to determine agronomic variability among segregating maize populations derived from mutation breeding.

The objectives of this study were to determine agronomic variation among M$_3$ and M$_4$ maize lines derived from mutation breeding and to analyze the correlation between various agronomic traits with grain yield plant^{-1} and with herbicide tolerance. Such findings could assist maize breeders in the early identification of high yielding maize lines.

2.0 MATERIALS AND METHODS

The study was conducted in Juja, Jomo Kenyatta University of Agriculture and Technology Farm, from October, 2014 to September, 2015 under rainfed conditions and supplementary irrigation was provided when necessary. Juja is located 36km North-East of Nairobi along the Thika-Nairobi highway. It lies between latitudes 3° 35"S and Longitudes of 36º 35"E (GoK 1997). Juja is located in the upper midland zone four which is semi- humid to semi-arid at1520 meters above sea level with a mean annual temperature of 20ºC and mean maximum temperature of 30ºC (Muchena et al. 1978; Wanjogu and Kamoni 1986). The area receives low rainfall of 856mm with a bimodal distribution with the October–December short-rains season and the April–August long-rains season (Kaluli et al., 2011).The area has three types of soil which are shallow clay soils over trachytic tuff with very shallow sandy clay soils over murram and deep clay (Vertisols) soils (Batjes, 2006).

2.1 Plant materials

Thirty nine (39) M_3 and 37 M_4 maize lines and a check were used in this study and were developed as follows: In August 2013, two maize hybrids namely H513 and H520, were bought from the Kenya Seed Company. About 5,000 maize kernels of each of the two maize varieties were mutagenized using the procedures reported for wheat by Newhouse et al., 1992 and for sorghum by Ndung'u (2009) with minor modifications. Maize kernels were soaked in water for 12 hours at room temperature, dried in tissue paper and then placed for 6 hours in jars containing 250 ml of 0.1% ethanemethyl sulfornate (EMS) solution which completely immersed the seeds.

The mutagenized seeds were washed under running tap water for 10 minutes to eliminate the mutagen and dried on paper towels. The mutagenized seeds (M_0) were then planted in the field in JKUAT. The M_1 plants arising from these seeds were self- pollinated at anthesis and M_2 seeds bulk harvested from them at maturity. The grains were threshed and about 1.8 million M_2 seedlings drilled in furrows. Two weeks after emergence, the seedlings were sprayed with 1% glyphosate 480 SL using a knapsack sprayer. All susceptible plants died within two weeks after spraying. The surviving plants were allowed to continue growth, self- pollinated at anthesis, and each plant harvested singly at maturity to give M_3 seeds. Only plants producing twenty (20) or more seeds per cob were considered for further evaluation.

The M_3 seeds from each plant was divided into two portions: one portion to screen for herbicide tolerance and the other portion for agro-morphological characterization and advancement to the next generation. During characterization of M_3 lines, thirty seven (37) agronomically desirable plants were selected for evaluation in the M_4 generation. The M_4 seed from each selected plant was divided into two portions: one portion to screen for herbicide tolerance and the other portion for agro-morphological characterization.

2.2 Treatments and experimental design:

2.2.1 Screening for herbicide tolerance

The 39 M_3 lines and a local check (H520) were evaluated during the period March to August, 2015 while the 37 M_4 lines were evaluated in September to October 2015 using randomized complete block design with two replications. A random sample of 5-50 seeds from each line was drilled in single rows in furrows of 1m long. Ten days after emergence, the seedlings were sprayed with x1 glyphosate. Starting from 4th day after spraying, the seedlings were scored for tolerance to the herbicide. The visual symptoms on susceptible plants commenced with yellowing, followed by browning, wilting and eventually death. Data on the number of days taken from spraying to eventual death of all plants in a row was recorded and used as a measure of tolerance.

2.3 Data Collection

Five plants were randomly selected from the middle of each row and tagged. Data on various agro- morphological characters were recorded on each of the pre-tagged plants at various phenological stages of growth as follows:

Table 1: Full names, abbreviations and descriptions of the traits evaluated in this study.

S no.	Trait name	Denotation	Description
1	Tolerance days	TLD	Counted from the first day after spraying to eventual death or constant number of plant(s) surviving in a line
2	Plant height	PH	Measured with a metric tape as the distance in cm from the ground level to the to the tip of the tassel at harvest stage
3	Total ears plant[-1]	TEP	Achieved by counting the actual number of ears on the maize line and averaged as ears plant[1-].
4	Ear length	EL	The distance in cm from the ground level to the uppermost node bearing a primary ear
5	Ear diameter	ED	The length of the ear in cm from the base to the tip of a dehusked ear
6	Ear length	EL	Taken as the average of number of rows counted on each of the five cobs
7	Grains row[-1]	NGR	Taken as the average of number of grains counted on five rows of each selected ear after harvest
8	Grains ear[-1]	NGE	Obtained by the following equation: NGE= NRE×NGR**.**
9	Hundred seed	SW	A random sample of one hundred grains from each cob was weighed with an electronic weighing balance after drying the grains to

	weight		uniform moisture content.
10	Grain yield plant^{-1}	GY	The threshed grains from each cob were weighed with an electronic weighing balance after drying to uniform moisture content

2.4 Data analysis

Data for various agronomical traits were subjected to variance (ANOVA) and significant mean values separated using LSD at 5% level of significance using Genstat statistical software release 14.1 (Payne et al. 2011). Association among the agronomic traits was obtained using Pearson Correlation Coefficients.

3.0 RESULTS AND DISCUSSION

3.1 Variation in agronomical traits

Analysis of variance showed that all traits in the M_3 (Table 2) and M_4 (Table 4) generations were significantly different except rows ear^{-1} and number of ears plant^{-1}.

Yield and Yield Related Traits for M_3 and M_4 Generations

Plant height

The mean values for plant height among the M_3 lines ranged between 105.3cm to 288.2cm with a grand mean of 227.2cm. The tallest were M_3 lines 520-62, 520-47, 520-58 and 520-78 which recorded 267.8cm, 267.3cm, 260.5 cm and 256.0 cm respectively. The lowest plant height was recorded on maize line 513-16 (169.7 cm). All the test lines were shorter than the check cultivar (302.4 cm) (Table 3). In the M_4 generation, plant height ranged between 188.4 cm to 306.6cm with a grand mean of 261cm. The tallest were recorded on maize lines 520-51_4, 520-56_3, 520-78_3, and 520-24_1 which recorded 298.3cm, 295.7cm, 292.1cm and 287.1cm respectively. The lowest plant height was recorded in line 520-4_5 (202.8cm) (Table 5). The mean plant height for the test materials and the check variety during the second season was higher than that for the first season. Thus the mean for M_4 was higher than that for M_3 lines. The higher mean plant height values were attributed to the higher rainfall received during that season compared to the amounts received in the previous season. The M_4 line 520-78-3 inherited the tall stature from its tall M_3 parent line 520-78. The results in this study are in agreement with previous reports by Ahmad et al. (2011), Charles et al. (2013) and Anonymous, (2014) who reported significant variability among the maize genotypes for plant height.

Ear height

The mean values for ear height among the M_3 lines ranged from 61.33 to 156.0 cm with a grand mean of 106.5 cm (Table 3). The highest ear height was recorded in maize lines 520-62, 520-35, 520-43 and 520-56 recording 127.5 cm, 126.9, 126.5 and 126.5cm respectively (Table 2). The lowest ear height was recorded on line 513-12(79.0 cm). All the test lines had lower ear height than the check variety (167.6cm). The ear height values for the M_4 lines ranged between 96.33cm to 267.9cm with a grand mean of 162.1cm. The highest recorded ear heights were in lines 520-51_4, 520-28_2 and 520-67_5 recording 247.5cm, 226.8cm and 214.9cm respectively. The lowest ear height was recorded in line 520-81_5 (119.8cm) (Table 5). The mean ear height values were higher during the second than during the first season. Just as in the case of plant height, the higher ear heights were attributed to higher rainfall during the second season compared to the first season. These results are in line with those of Zahid et al. (2004) and Baqa et al. (2014) who also opined that ear height is one of the most desirable traits in the selection of good maize genotypes .

Ear length

The mean ear length values in M_3 ranged from 12.6 to 21.63 cm with grand mean of 19.3 cm. The highest ear lengths were recorded in lines 520-62, 520-83 and 520-51 recording 22.3 cm, 21.6 cm and 21.3 cm respectively. The lowest ear length was recorded in line 520-47(15.47 cm) (Table 2). All the maize lines had shorter ear length than the check (23.2cm) (Table 3). The ear length in M_4 lines ranged between 10.9cm to 24.7cm with a grand mean of 18.7cm. The greatest ear length was recorded in lines 520-58_2, 520-51_4 and 520-24_1 recording 21.9cm, 21.7cm and 21.7 respectively. The lowest ear length was in line 520-67_3 (15.6cm) (Table 5). Mean ear length values were higher during the first season than the second season. This indicated that the higher rainfall received during the second season than in the first season did not result in taller ears, although it resulted in taller plants and higher ear lengths. The source of variations among the maize lines could be attributed possibly to varietal differences and to a lesser extent environmental differences during the growing period. Mean ear length values were higher during the first season than the second season. This indicated that the higher rainfall received during the second season than in the first season did not result in taller ears, although it resulted in taller plants and higher ear lengths. Due to the phenotypic variations, maize breeder could indirectly select on ear length which is easily measured and heritable trait to indirectly select for increased grain yield plant^{-1} genetic gain. The results in this study on ear length were in agreement with those of Galarreta and Alvarez (1990), Shamim et al. (2010) , Singh and Chauhan (2010)and Malik et al. (2011) who reported highly significant differences among maize hybrids for the character. However, the results were in disagreement with those of Kashiani et al (2010) who reported non-significant differences for this trait.

Hundred seed weight

The mean hundred seed weight in M_3 ranged from 11.80g to 31.26g with a grand mean weight for a hundred seeds was 20.88g. The highest hundred seed weight was recorded among inbred lines 520-58, 520-43, 520-63 and 520-67 recording 26.86g, 25.89g and 24.04g respectively lower than check variety (31.31g). The lowest recorded hundred seed weight was in maize line 520-37 recording 16.17g (Table 3). The mean hundred seed weight in M_4 maize lines characterized ranged between 12.53g to 43.47g with a grand mean of 20.73g. The highest recorded hundred seed weight were in maize lines 520-4_5 , 520-38_5 , 520-4_3 and 520-83_5 recording 37.94g, 25.04g, 24.43g and 24.18g respectively lower than the check variety (44.32g). The lowest recorded hundred seed weight was in line 520-56_3 (15.33g) (Table 5). A hundred seed weight probably could be attributed to genetic make-up of the maize lines and mutagenesis effects. The maize breeder could pay special attention to the quantitative trait for direct development of high yielding maize genotypes in future breeding programmes. The evaluated maize lines for a hundred seed weight could be categorized mainly into heavy, medium and low weighted grains. The high seed weight are characterized by wider seed diameter, bigger seed length and thickness characterized by proper grain filling. The maize breeder could utilize maize line with heavier grain weight to develop maize genotypes for high grain yield plant future breeding programmes. Tatenda (2013); Aman et al. (2016 and Turi et al. (2007) had previously found similar findings citing that observed differences could be as a result genetic make-up differences.

Number of rows ear^{-1}

There were no significant differences among the maize lines for number of rows ear^{-1} (Table 1 and 3). However, there were considerable differences in the mean values among the lines for the trait (Table 2 and 4). The mean values for the number of rows ear^{-1} among the M_3 lines characterized ranged from 11.4 to 16.4 with a grand mean of 13.74. The highest number of rows ear^{-1} was recorded in maize lines 520-61, 520-14, 520-28 and 520-50 recording 15.07, 15.0, 14.8 and 14.8 respectively. The lowest number of rows ear^{-1} was recorded in line 520-27 (12.47) (Table 3). All the maize lines had fewer rows ear^{-1} compared to the check (14.33). The number of rows ear^{-1} among the M_4 lines characterized ranged from 20.75 to 42 with a grand mean of 18.5. The highest number of rows ear^{-1} among the maize lines were in lines 520-32_5, 520-38_5, 520-28_2 and 520-51_3 recording 17.25, 15.87, 15.4 and 15.2 respectively which was lower than the check (44.12). This probably could have resulted more from genetic differences than environment among the maize lines. This implies that row number for any given maize line will be quite similar from year to year, regardless of growing conditions. The higher the number of rows ear^{-1}, the higher the grain yield. This only applies when all the rows ear^{-1} have fully set grains and the length of the ear is long enough to take up more grains row^{-1}. The phenotypic variations in the number of rows ear^{-1}could be utilized by the breeder as a basis for further

indirect development of high yielding maize genotypes. The maize lines could be classified into high, intermediate or low rows ear[-1] with high number of rows ear[-1] desired by maize growers for their yield. Ghimire and Timsina (2015) and Omondi et al. (2014)obtained contrary results as they obtained significant differences for the rows ear [-1] but Syafii et al. (2015) and Kinfe and Tsehaye (2015) results were in strong congruence to current study indicating that the maize lines should first be screened for genetic diversity ensuring success in developing new high yielding cultivars which by relying on the availability of genetically diverse germplasm (Buckler et al., 2009). The higher the genetic diversity possessed, the greater the chances for developing new superior cultivars. Germplasm improvement and genetic diversity is a key to reliable and sustainable production of the food crops through breeding. The genetic variability for rows ear[-1] shown by the maize lines can be used for the development of the high yielding and better performing variety.

Number of grains row[-1]

The mean values for the number of grains row[-1] among the M_3 lines characterized ranged from 15.20 to 39.80 with a grand mean of 29.43. The highest number of grains row[-1] was recorded in maize lines 520-62, 520-51, 520-50 and 520-28 recording 36.20, 34.53, 33.93 and 33.40 respectively. The lowest number of grains row[-1] was recorded in line 520-72 (23.07) (Table 3). All the maize lines had fewer grains row[-1] compared to the check (42.87). The number of grains row[-1] among the M_4 lines characterized ranged from 20.75 to 42 with a grand mean of 31.25. The highest number of grains row[-1] among the maize lines were in line 520-51_5, 520-61_4, 520-51_2 and 520-67_5 recording 38.7, 36.02, 36.0 and 34.9 respectively which was lower than the check (44.12) as shown in Table 5. Grains ear[-1] could possibly as a result of genetic factors. The maize lines could be categorized into high, medium and low grained ear[-1]. The breeder could utilize the substantial genetic variability to select ears with high grains row[-1] which would translate into high yields in the future breeding programmes. In conformity to our findings, Rebourg et al. (2001), Reddy et al. (2012) and Muhammad et al. (2010) indicated a considerably strong genetic variation in the experimental material resulting in significantly high grain yield hence total grain production.

Number of grains ear[-1]

The mean values of the number of grains ear[-1] among the M_3 lines characterized ranged from 218.4 to 576.4 with a grand mean of 400.3. The highest number of grains ear[-1] was recorded in the maize lines 520_62, 520_50 520_28 and 520_51 recording 496.7, 484.6, 474.3 and 472.2 grains, respectively. The lowest number of grains ear[-1] was recorded in inbred line 520-47 (324.3). All the M_3 maize lines recorded lower grains ear[-1] than the check (645.7) (Table 3). In M_4, the mean values of maize lines ranged from 273.4 to 704.8 with a grand mean of 418. The

highest recorded number of grains ear^{-1} were recorded in maize lines 520-58_2, 520-28_4, 520-51_3 and 520-61_3 with 571.2, 528, 506.8and 486.8 grains, respectively. Maize line 520-78_3 recorded the lowest number of grains ear^{-1} with 328.5 (Table 5). This could be possibly as a result of varietal differences among the lines tested. The maize breeder could exploit the trait genetical variability to select and breed for novel varieties, synthetics or composites with greater number of grains ear^{-1} for higher grain yield improvement in future. Similar results were obtained by Tulu (2014) who revealed that the trait plays a vital role in enhancement of grain yield and a lot of emphasis should be given to this trait during selection. Contrasting results were observed by Singh and Chauhan (2010) who recorded non-significant variations among the genotypes for the trait. However, their results indicated similar findings for the number of grains ear^{-1} differences among the entries for the trait.

Total number of ears plant^{-1}

There were no considerable significant differences among the 39 M_3 and 37 M_4 maize lines for ears plant^{-1} (Table 2 and 4). However, the mean values for the characterized M_3 and M_4 maize lines for the ears plant^{-1} showed varied phenotypic differences among them (Table 3 and 5). The mean values of ears plant^{-1} among the M_3 lines characterized ranged from 1.2 to 8.0 with a grand mean of 3.17. The highest number of ears plant^{-1} was recorded in the maize lines 520_62, 520_70 520_83, 520-32 and 520_43 recording 5.3, 4.0, 4.0, 3.9 and 3.9 ears plant^{-1} respectively. The lowest number of ears plant^{-1} was recorded in maize line 520-37 (2.0). All the M_3 maize lines recorded lower grains ear^{-1} than the check (645.7) (Table 3). In M_4, the mean values of maize lines ranged from 273.4 to 704.8 with a grand mean of 418. The highest recorded number of ears plant^{-1} were recorded in maize lines 520-68_1, 520-51_3, 520-58_1 and 520-56_1 with 3.0, 2.6, 2.5 and 2.4 respectively. Maize line 520-38_3 recorded the lowest number of ears plant^{-1} with 1.5 (Table 5). This probably resulted from varietal differences among the maize lines for the trait. The number of ears plant^{-1} have a direct influence on the grain yield plant^{-1}. The number of ears plant^{-1} can be categorized into high, medium and low. The maize breeder could select optimal or intermediate total number of ears plant^{-1} for future breeding programmes aimed at improvement of maize genotypes. High total number of ears could compromise on grain yield as this results to competition for the photo-assimilates at the expense of ear expansion and grain filling. Zamir et al. (2011) reported significant amount of variability for the trait while Silva et al. (2010) reported non-significant differences in the total number of ears plant^{-1} with sufficient differences among the variants indicating the trait is not influenced by environmental conditions but is genetically controlled.

Grain yield plant^{-1}

The mean values of the characterized M_3 maize lines ranged from .6.3g to 154.0g with a grand mean of characterized M_3 inbred lines was 82.1g. The highest recorded grain yield plant^{-1} was recorded in line 520-58, 520-61, 520-28 and 520-51 recording 116.2g, 115.6g, 109.8g and 109.1 g respectively. The lowest recorded grain yield plant^{-1} was in line 513-12 (34.6g). All the lines recorded lower grain yield plant^{-1} than the check (165.3g) (Table 3). The M_4 mean values of characterized maize lines ranged from 34.8 g to 181.2 g with a grand mean of 93. The greatest recorded grain yield plant^{-1} were in maize lines 520-38_3, 520-51_5, 520-78_3 and 520-56_1 with 151.5g, 146.9g, 137.1 and 127.3g, respectively. The lowest recorded grain weight plant^{-1} was in line 520-56_1 with 61.2g (Table 5). The trait could be categorized into high, medium and low yielding cultivars. Higher grain yield plant^{-1} among the progenies than the parental lines in the breeding programmes is the main aim for the development of high yielding as well as well adapted cultivars, composites, synthetics or varieties to other desirable attributes such as high protein, drought tolerant, herbicide tolerance and other abiotic and abiotic stressors. Breeding for improved varieties and/or hybrids is a continuous process and requires a thoroughly understanding of the genetic mechanisms governing yield and yield related components. Higher grain yield among the maize lines indicates the potential of the specific lines to convert the photosynthates into dry matter. Alan et al. (2013), Ali et al. (2014) and Golam et al. (2011a) results were in congruence with our results.

Ear diameter

The mean values of the characterized M_3 maize lines ranged between 2.50 cm to 4.90cm with a grand mean of 3.92 cm. The highest ear diameter was recorded in maize lines 520-38, 520-51, 520-63 and 520-72 recording 4.26 cm, 4.21cm, 4.18cm and 4.16cm respectively which was lower than the check variety (4.44 cm). The lowest ear diameter recorded was in line 513-12 (2.99 cm) (Table 3). Ear diameter of M_4 lines ranged between 3cm to 6.56cm recording a grand mean of 4.05cm. The greatest diameter was recorded in maize lines 520-51_4, 520-28_2, 520-63_1 and 520-65_4 recording 5.95cm, 4.45cm, 4.34cm and 4.34cm respectively. Similarly, all lines recorded lower ear diameter than the variety check (6.87cm). The lowest ear diameter was recorded in line 520-4_3 with 3.53cm (Table 5). The variability among the maize lines could be as a result of varietal differences, environmental conditions and mutagenic effects. The breeder could utilize the genetic variability present in the populations for enhanced grain yield plant^{-1} in future breeding programmes Variability in the morphological trait in maize is important in improvement of grain yield as long as the ear is long, wide and properly set grains. In line with these findings, Kashiani et al. (2010); Dorijana et al., (2012) and Langade et al., (2013) reported similar findings in maize.

Herbicide Tolerance Days

The mean values of the characterized maize lines in M_3 lines ranged from 6 to 23.67 days with a grand mean value of 17.18 days. The highest tolerance was recorded in lines 520-42, 520-25, 520-63 and 520-12 recording 23.67, 22.67, 22.67 and 22 days compared to the check variety which recorded fewer tolerance days (6.00 days). The lowest herbicide tolerance was recorded in lines 520-81 (11days) (Table 3). In 37 M_4 maize lines, the mean values ranged from 10 to 32 days with a grand mean of 26.5 days. The most tolerance lines were 520-38_3, 520-38_5, 520-28_4 and 520-4_5 recording 28.5, 27.31, 26 and 25.5 days, values that were higher than the check variety (7.00 days). The lowest tolerance was recorded in maize lines 520-83_5 (13.5 days) (Table 5). The maize lines could be categorized into highly tolerant, medium and low tolerant. The tolerance levels could have been as a result of genetic make-up arising from the mutagenic effects. The maize breeder could utilize the most tolerant lines to develop herbicide tolerant hybrids, synthetics or composites leading to excellent weed control hence higher crop yields, reduced soil erosion and soil compaction due to fewer tillage, reduced numbers of sprays in a season and less herbicide application as well as reduced fuel costs, use of low toxicity compounds which do not remain active in the soil and ability to use no-till or conservation-till systems maintaining soil structure and soil organisms(Powell et al., 2009;Rizwan et al., 2015).

Table 2: Analysis of variance (ANOVA) of grain yield and other agronomic traits of 39 M_3 maize lines

Character	DF	Sum of Squares(SS)	Mean Squares(MS)	P. value	%CV
Plant height(cm)	36	73378.00	1881.0	0.013	14.0
Tolerance days	39	1617.99	41.49	<0.001	11.1
Ear diameter(cm)	36	8.214	0.2106	0.019	8.8
Ear length(cm)	36	341.725	8.762	0.046	12.2
100 seed weight(g)	36	963.750	24.71	0.023	18.0
Grain yield plant^{-1}(g)	36	54267.20	1391.5	0.006	32.5
Grain row^{-}	36	1458.050	37.39	0.046	16.4
Grain ear^{-1}	36	384759.00	9866	0.017	18.4
Rows ear^{-1}	36	48.495	1.243	0.520	8.2
Ear height(cm)	36	29915.90	767.1	0.044	20.4
Total ears plant^{-1}	36	45.837	1.1753	0.209	30.9

Significant at 5% level of probability
Note: DF= degree of freedom, CV % = Coefficient of variation, PH= Plant height, EL= Length of ear, ED= ear diameter, GY= Grain yield/plant, SW= 100 Seed weight, EH= Ear height, NGE= Number of grains ear^{-1}, NGR= Number of grains row^{-1} and NRE= Number of rows ear^{-1}

Table 3: Mean values for grain yield and other agronomic traits of 39 maize lines at JKUAT in 2015

M₃ Line	PH	EH	EL	ED	TEP	NRE	NGR	NGE	SW	GY	TLD
520-4	246.5	107.7	21.27	3.95	2.9	14.07	26.13	368.2	21.10	79.3	16.00
520-6	234.9	123.6	19.30	3.82	2.4	13.13	32.47	389.9	21.26	74.6	20.33
513-12	193.3	79.0	19.60	2.99	2.7	13.40	30.40	443.7	21.49	34.6	22.00
520-14	239.1	122.3	21.07	3.65	2.7	15.00	29.13	432.5	17.72	69.0	19.67
513-16	169.7	92.7	18.93	3.84	3.0	14.00	30.00	416.7	18.76	73.3	18.33
520-22	228.3	110.2	18.27	3.67	2.6	13.47	29.20	379.3	18.66	64.8	20.33
520-23	230.0	100.5	18.70	4.15	2.9	14.13	28.07	382.0	21.31	79.9	18.33
520-24	209.5	89.5	18.60	3.86	2.2	14.40	31.67	450.8	17.47	69.7	16.67
520-25	196.4	81.3	17.84	3.83	2.8	13.20	28.73	374.0	19.92	91.5	22.67
520-27	217.9	101.0	17.00	3.22	3.6	12.47	26.33	376.9	18.88	57.4	20.33
520-28	246.7	110.0	21.20	4.01	3.5	14.8	34.53	474.3	22.01	109.8	15.00
520-29	210.4	93.1	18.57	4.09	2.5	13.87	29.33	397.0	21.27	82.9	15.00
520-31	198.6	98.6	18.23	3.94	2.5	14.67	25.80	387.3	17.32	64.6	16.67
520-32	209.3	90.7	20.30	3.76	3.9	12.80	31.47	394.7	20.53	77.9	20.33
520-34	226.1	103.8	20.50	4.09	3.2	13.67	28.93	384.9	18.97	66.8	20.33
520-35	251.8	126.9	18.60	3.93	3.1	13.93	31.47	436.9	19.98	84.1	17.33
520-36	205.6	103.0	19.57	3.81	3.9	13.13	29.27	385.8	18.06	64.1	15.67
520-37	174.5	86.3	16.50	3.61	2.0	12.93	30.60	385.7	16.17	70.6	19.67
520-38	227.7	108.7	19.87	4.26	3.4	13.27	28.27	383.5	22.35	83.5	13.00
520-41	226.1	108.8	18.17	4.01	3.4	14.00	25.60	394.2	21.83	71.0	20.67
520-42	232.6	109.6	20.70	4.04	3.4	13.53	28.20	366.0	21.55	93.5	23.67
520-43	267.3	126.5	20.00	4.11	3.9	13.07	29.47	398.9	25.89	89.9	20.00
520-47	211.5	104.5	15.47	4.15	3.2	13.40	26.20	324.3	21.33	76.1	14.67
520-50	231.8	109.7	19.47	3.88	3.1	14.80	33.40	484.6	16.43	73.1	16.00
520-51	248.5	118.5	21.33	4.21	3.8	14.13	33.93	472.2	23.50	109.1	21.33
520-56	260.5	126.5	18.63	3.95	3.4	13.33	28.27	378.5	19.88	71.2	15.67
520-58	231.9	106.8	20.40	4.13	3.3	12.73	28.60	372.0	26.86	116.2	18.00
520-61	233.3	99.5	20.80	4.07	3.2	15.07	32.13	439.8	22.84	115.6	16.00

M_3 Line	PH	EH	EL	ED	TEP	NRE	NGR	NGE	SW	GY	TLD
520-62	267.8	127.5	22.30	3.88	5.3	13.60	36.20	496.7	21.47	101.2	14.67
520-63	207.7	87.8	19.33	4.18	3.3	13.60	28.47	388.5	24.04	88.5	22.67
520-65	238.9	111.5	17.07	3.92	2.6	13.87	26.27	367.9	19.90	69.1	15.00
520-67	240.9	104.9	20.67	4.14	3.2	14.73	30.13	442.3	23.95	91.7	19.33
520-69	235.5	107.3	17.53	3.87	2.7	13.73	23.27	329.1	20.79	67.5	18.67
520-70	228.3	113.5	17.03	4.08	4.0	13.47	28.60	341.4	21.90	99.0	13.33
520-71	230.8	99.2	17.53	3.73	2.4	14.07	23.07	327.1	21.03	58.4	12.33
520-72	256.0	118.8	21.03	4.16	3.0	13.27	30.07	399.8	23.85	67.7	14.00
520-78	237.1	124.8	17.7	3.91	3.4	13.13	31.13	366.9	20.58	83.0	11.33
520-81	227.3	113.7	20.2	4.13	3.3	13.53	31.20	425.3	22.57	92.8	11.00
520-83	230.9	104.7	21.63	4.13	4.0	14.00	31.93	452.3	20.82	87.0	15.00
Mean	227.2	106.5	19.25	3.927	3.17	13.74	29.43	400.34	20.88	80.0	17.18
Maximum	288.2	156.0	26.2	4.90	8.0	16.40	38.80	576.40	31.26	154.0	23.67
Minimum	105.3	61.33	12.6	2.50	1.2	11.40	15.20	218.40	11.80	6.3	11.00
Check(H520)	302.4	167.6	23.23	4.44	2.5	14.33	42.87	645.70	31.31	165.3	6.00

Note: TLD= Tolerance days, PH= Plant height, EH= Ear height, EL= ear length, ED= diameter of ear, NGR= No. of grains/row, NGE= No. of grains ear[-1], SW= 100 seeds weight, NRE= number of grains row[-1], TEP= total number of ears plant[-1],GY- Grain Yield plant[-1]

Table 4: Analysis of variance (ANOVA) of grain yield and other agronomic traits of 37 M_4 maize lines

Character	DF	Sum of Squares(SS)	Mean Squares(MS)	P. value	%CV
Plant height(cm)	36	33613.3	933.7	0.020	8.3
Tolerance days	36	1543.764	42.88	<0.001	12.0
Ear diameter(cm)	36	11.74	0.3261	0.018	9.9
Ear length(cm)	36	354338	9.843	0.006	11.0
100 Seed weight(g)	36	1148.64	31.91	0.01	18.3
Grain yield plant[-1](g)	36	37790.9	1049.7	0.04	9.0
Grain row[-1]	36	853.80	23.72	0.03	11.3
Grain ear[-1]	36	245688	6825	0.028	14.3
Rows ear	36	78.301	2.175	0.924	13.4
Ear height	36	42361.0	1176.7	0.030	15.4
Total ears plant[-1]	36	7.5858	0.2107	0.805	25.9

Significant at 5% level of probability
Abbreviations: DF= degree of freedom, CV % = Coefficient of variation

Table 5: Mean values for grain yield and other agronomic traits of 37 M_4 maize lines in JKUAT in 2015/2016

M_4 Line	PH	EH	EL	ED	TEP	NRE	NGR	NGE	SW	GY	TLD
520-51_4	298.3	247.5	21.71	5.950	2.400	13.6	33.20	452.9	20.16	116.6	23.00
520-83_5	244.3	150	17.54	4.068	2.300	14.10	34.70	484.9	24.18	104.5	13.50
520-67_5	278.4	214.9	19.35	3.9250	2.100	13.40	34.90	451.7	21.66	89.1	19.00
520-4_1	286.8	155.3	19.82	3.810	2.433	13.50	27.13	316.6	18.25	98.4	22.00
520-51_3	238.5	175.8	16.73	3.587	2.300	14.40	28.30	346.6	15.89	63.1	21.00
520-65_4	254.3	153.5	18.35	4.335	2.100	13.60	32.70	430.7	22.47	96.2	21.50
520-83_1	253.6	168.1	16.68	4.232	2.300	14.80	24.40	436.5	19.06	66.2	17.50
520-23_3	247.1	142.7	17.66	3.910	1.800	17.25	32.25	400.1	20.50	108.8	14.31
520-58_1	257.1	153.9	16.67	3.900	2.300	13.90	30.10	401.6	21.56	92.0	21.50
520-51_2	272.7	179.1	20.96	4.040	1.900	13.60	36.00	376.6	19.89	90.2	22.50
520-32_5	281.5	172.0	20.15	4.320	1.950	14.75	34.80	348.2	23.04	70.9	22.00
520-41_1	274.7	168.6	18.48	4.000	2.300	14.20	31.00	382.4	15.80	74.3	17.69
520-28_2	225.1	226.8	19.41	4.450	2.475	13.90	33.50	437.2	21.13	98.4	22.23
520-67_3	250.3	164.1	15.60	4.227	3.000	14.60	29.50	395.1	21.37	98.1	23.50
520-38_5	263.5	167.6	20.75	3.580	2.200	14.00	27.00	315.5	25.04	76.3	27.31
520-28_4	253.4	162.4	17.22	4.140	1.800	15.40	33.00	528.0	17.30	79.6	26.00
520-63_1	278.1	190.2	17.40	4.340	1.800	12.60	30.90	350.0	19.73	65.3	24.50
520-28_2	267.5	155.3	17.00	3.967	1.700	12.25	28.60	445.0	22.45	88.7	23.50
520-28-1	275.1	156.1	17.49	4.095	1.750	14.65	28.90	415.7	18.29	99.0	16.50
520-4-5	202.8	160.1	16.86	4.120	1.633	13.13	32.23	452.8	37.94	116.4	25.50
520-58_2	261.2	153.5	21.88	4.320	1.725	13.75	30.47	571.2	21.08	77.4	21.50
520-4_3	263.3	148.2	19.22	3.530	1.975	14.13	30.90	452.9	24.43	113.5	25.00
520-56_3	295.7	157.7	17.63	3.535	1.700	15.87	26.87	454.2	15.33	61.2	21.50
520-56_1	266.8	151.8	18.85	3.860	2.025	14.08	32.25	380.6	23.30	127.3	20.00
520-38_3	244.8	145.7	21.50	3.930	2.100	12.60	35.55	445.8	26.89	151.5	28.50
520-38_2	284.1	156.4	17.34	3.770	1.700	14.05	33.45	430.0	19.45	107.2	24.50
520-58_3	269.3	150.0	11.07	4.070	2.100	14.00	31.10	402.2	20.14	107.8	24.50
520-78_3	292.1	160.2	19.16	3.845	2.400	15.10	32.50	328.5	21.60	137.1	21.00
520-61_4	251.3	149.2	21.53	3.840	2.000	13.60	32.50	354.3	18.23	84.9	21.50
520-61_3	226.0	143.9	20.29	3.917	1.600	13.40	28.40	486.8	17.91	68.5	19.50
520-4_2	249.2	143.2	21.87	3.655	2.175	12.65	31.77	410.4	19.95	87.3	22.50
520-81_5	220.8	119.8	17.72	4.200	1.633	15.00	32.12	438.1	15.39	69.1	17.50
520-51_3	251.8	162.3	19.51	4.010	2.100	12.40	32.60	506.8	19.59	85.8	24.00
520-61_4	270.9	144.3	18.38	4.150	2.000	13.87	36.02	450.0	17.14	83.9	17.00
520-51_5	268.9	142.3	16.94	4.367	2.600	15.20	38.70	450.6	17.79	146.9	24.50
520-24_1	287.1	164.3	21.70	3.755	1.975	12.15	24.35	386.4	21.48	69.9	23.50
520-69_1	249	141.3	20.82	4.000	1.500	14.00	23.60	348.6	21.46	103.7	19.50
Mean	261	162.1	18.68	4.047	2.050	13.99	31.25	418.0	20.73	93.9	26.50
Maximum	306.6	267.9	24.74	6.560	3.600	20.00	42.00	704.8	43.47	181.2	32.00
Minimum	188.4	96.33	10.89	3.000	1.000	9.67	20.75	273.4	12.53	34.8	10.00
Check(H520)	307.8	182.6	12.36	6.870	2.700	18.50	44.12	723.1	44.32	183.5	7.00

Note: PH= Plant height, EH=Ear height, EL= ear length, ED=diameter of ear, NGR=No. of grains/row, NGE= No. of grains ear^{-1}, SW= 100 seeds weight, NRE= number of grains row^{-1}, TEP= total number of ears plant^{-1}, GY- Grain Yield plant^{-1}

3.3 Correlation among agronomic traits recorded in M_3 and M_4 maize lines

Results on Pearson's Correlation analysis of studied traits among 39 M_3 and 37 M_4 maize lines are presented in Tables 6 and 7. Results for the M_3 generation indicated positive and significant correlation between grain yield plant $^{-1}$ and other agronomic traits but significant (P<0.05) and negative correlation with herbicide tolerance days (r=-0.36*). Significant and positive correlation (Table 6) of grain yield plant^{-1} was recorded with plant height (r =0.55**), ear height (r =0.76**), ear length (r =0.68**), ear diameter (r =0.67**), number of rows ear^{-1} (r =0.52**), hundred seed weight (r =0.65**) and number of grains row^{-1} (r =0.29**). This positive correlation indicate that an increase in any one of these traits would result in an increase in yield of the test genotypes. The negative correlation between grain yield plant^{-1} and herbicide tolerance indicates that improvement in herbicide tolerance would lead to a decline in grain yield plant^{-1}. The mutagenic effect had a strong negative impact on grain yield plant^{-1} *per se* by impacting negatively on grains ear^{-1} and row^{-1}, plant height, hundred seed weight, ear height and diameter which are crucial traits in yield determination that would otherwise have significantly contribute to improved grain yield.plant^{-1}. These finding are in line with those of Venugopal et al. (2003) and Kanagarasu et al. (2012) Kashiani et al. (2010) and Saleh et al. (2002) in maize. In the M_4 generation, grain yield plant^{-1} showed highly significant (P<0.01) and positive correlation with hundred seed weight (r=0.43**) and number of grains row^{-1} (r = 0.46**). Grain yield plant^{-1} exhibited significant and negative correlation with tolerance days (r=-0.27*) (Table 7). The effect of mutagen causes changes in genetic make-up leading to phenotypic changes enhancing agro-morphological variability such as plant height and tolerance days. The results of the current study were in agreement with those of Venugopal et al. (2003) and Kanagarasu et al. (2012) Kashiani et al. (2010) and Saleh et al.(2002) in maize and Ndou et al., (2015) in wheat. However grain yield plant^{-1} also exhibited non-significant correlation with all the other agronomic traits studied (Table 6) and was in agreement with Akeel et al. (2010).

In the M_3 generation, herbicide tolerance showed highly significant and negative correlation with all agronomic traits studied except in case of row plant^{-1} and total ear plant^{-1} where no significant correlations were recorded (Table 6). Significant correlations of herbicide tolerance were recorded with plant height (-0.41**), ear height (-0.47**). The negative correlations indicate that improvement in one of the traits would lead to a decline in the other trait.

In the M_4 generation, herbicide tolerance showed no significant correlation with all traits studied except in the case of rows ear^{-1} (-0.49**), 100 seed weight (0.36*) and grain yield plant^{-1} (-0.27*) where significant correlations were recorded. The negative correlations indicate that improvement in one of the traits would lead to a decline in the other trait.

In both M3 and M4 generations, grain yield was significantly and negatively correlated with herbicide tolerance. This indicates that herbicide tolerant lines incur some form of yield penalty and the two traits cannot be improved simultaneously.

Table 6: Correlations among yield and other agronomic traits for M$_3$ generation

Traits	TLD	PH	EH	EL	ED	TEP	NGE	SW	NGR	NRE	GY
TLD	1.00										
PH	-0.41**	1.00									
EH	-0.47**	0.83**	1.00								
EL	-0.21*	0.52**	0.41**	1.00							
ED	-0.22*	0.30**	0.24**	0.15^{ns}	1.00						
TEP	-0.12^{ns}	0.34**	0.19*	0.23*	0.17^{ns}	1.00					
NGE	-0.24*	0.29**	0.30**	0.46**	0.25**	0.06^{ns}	1.00				
SW	-0.31*	0.35**	0.27**	0.20*	0.52**	0.15^{ns}	0.16^{ns}	1.00			
NGR	-0.28*	0.23**	0.23**	0.42**	0.26**	0.16^{ns}	0.88**	0.14^{ns}	1.00		
NRE	-0.06^{ns}	0.27**	0.25**	0.23**	0.30**	-0.13^{ns}	0.42**	0.01^{ns}	0.16^{ns}	1.00	
GY	-0.36*	0.55**	0.76**	0.68**	0.67**	0.16^{ns}	0.52**	0.65**	0.52**	0.27**	1.00

Note: TLD= Tolerance days, PH= Plant height, EH= Ear height, EL= ear length, ED= diameter of ear, NGR= No. of grains/row, NGE= No. of grains ear^{-1}, SW= 100 seeds weight, NRE= number of grains row^{-1}, TEP= total number of ears plant^{-1}, GY= Grain Yield plant^{-1}

* = Significant, **= highly significant and ^{ns} = Non significant respectively

Table7: Correlations among yield and other agronomic traits for M_4 generation

Traits	TLD	PH	EH	EL	ED	TEP	NGE	SW	NGR	NRE	GY
TLD	1.00										
PH(cm)	0.02^{ns}	1.00									
EH(cm)	0.20^{ns}	0.27^{*}	1.00								
EL(cm)	0.05^{ns}	0.10^{ns}	0.16^{ns}	1.00							
ED(cm)	0.03^{ns}	0.10^{ns}	0.56^{**}	0.06^{ns}	1.00						
TEP	0.13^{ns}	0.13^{ns}	0.32^{*}	0.32^{*}	0.21^{ns}	1.00					
NGE	0.00^{ns}	-0.26^{*}	-0.03^{ns}	-0.03^{ns}	0.25^{*}	-0.23^{ns}	1.00				
SW(g)	0.36^{*}	-0.33^{*}	0.04^{ns}	0.07^{ns}	0.001^{ns}	-0.07^{ns}	0.03^{ns}	1.00			
NGR	0.08^{ns}	-0.03^{ns}	0.11^{ns}	0.00^{ns}	0.30^{*}	0.17^{ns}	0.27^{*}	0.10^{ns}	1.00		
NRE	-0.49^{**}	0.03^{ns}	-0.18^{ns}	-0.34^{*}	-0.03^{ns}	0.05^{ns}	-0.04^{ns}	-0.31^{*}	0.06^{ns}	1.00	
GY	-0.27*	0.02^{ns}	-0.07^{ns}	-0.03^{ns}	0.16^{ns}	0.27^{*}	0.003^{ns}	0.43^{**}	0.46^{**}	0.05^{ns}	1.00

Note: TLD= Tolerance days, PH= Plant height, EH= Ear height, EL= ear length, ED= diameter of ear, NGR= No. of grains/row, NGE= No. of grains ear^{-1}, SW= 100 seeds weight, NRE= number of grains row^{-1}, TEP= total number of ears plant^{-1}, GY- Grain Yield plant^{-1}

* = Significant, ** = highly significant and ^{ns} = Non significant respectively

CONCLUSION

From this study, it can be concluded that there were significant variations among the characterized M_3 and M_4 maize lines for essential traits like plant height, ear height, ear diameter, ear length, number of grains row^{-1}, number of grains ear^{-1}, hundred seed weight and grain yield plant^{-1} and herbicide tolerance. This implies that the available phenotypic differences among the maize lines could be a good source of variability for breeding programmes.

The current findings demonstrated that, in the M_3 generation, grain yield plant^{-1} showed positive and highly significant correlation with plant height, ear height, ear length, ear diameter, grains ear^{-1}, 100 seed weight and grains row^{-1}. In addition, tolerance days showed negative and highly significant correlations with plant height and ear height. Herbicide tolerance was negatively and significantly correlation with grain yield plant^{-1}. In the M_4 generation, grain yield plant^{-1} exhibited positive and highly significant correlation with 100 seed weight and grains row^{-1}.The results further demonstrated that herbicide tolerance correlated negatively and significantly with grain yield plant^{-1} and rows ear^{-1}. The positive and significant correlation suggest that such characters could be selected and improved simultaneously. The negative correlation indicated

that such traits cannot be improved simultaneously, and thus the breeder should decide on the priority traits in a breeding programmes. Grain yield and herbicide tolerance were negatively correlated in both M_3 and M_4 generations of this study and thus they could not be improved simultaneously.

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