OPEN ACCESS

Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 05 | Issue 03 | May-June | 2025
Journal homepage: https://gjrpublication.com/gjrals/

Original Research Article

Effect of Seed Storage Duration on Seed Yield and Yield Related Traits of Maize Inbred Lines

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DOI: 10.5281/zenodo.15491813 **Submission Date: 10 April 2025 | Published Date: 23 May 2025**

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Abstract

Yield and other yield related factors are badly affected by different factors. Biotic and abiotic factors are mainly those influence the final yield of different crops. Among the factors, maize crop is hardly affected by post- harvest techniques of crop process. From all post-harvest processes, storage duration and storage conditions are the factors that influence the quality and yield loss of the crop. This activity was proposed to investigate influence of storage duration on seed yield and yield related traits of maize inbred lines at Bako under ambient environmental conditions. Fifteen experimental combinations were combined together with five inbred lines Viz: CML395, CML202, CML312, CML165 and A-7033 stored for three different level of storage durations (5,17, and 29 months). The results of analysis of variance revealed that, crop phenology showed significant different among five inbred lines whereas failed to showed difference for storage durations. All growth traits were showed significant different for the interactions of the two main factors, while storage durations, inbred lines and interaction effects of the main factors was showed significant differences on plant aspect traits. It is recommended that, to have high quality and quantity of maize inbred lines, from these observations we conclude that it was an advisable to stored seed among five months and rejuvenating seed with the interval of five months will be retain the quality of the products.

Keywords: *Biotic, Abiotic, Inbredlines, Post-harvest, Storage duration.*

1. Introduction

Maize (*Zea mays* L.) is a primary staple crop; it's grown in nearly all agro-ecological zones in the country (USAID, 2010). Maize together with wheat and rice are the three most cultivated cereal crops worldwide (Suleiman *et al*., 2013). Current world maize production is about 10.14 billion metric tons (De Groote *et al*., 2013). The United States (US) is the largest producer, producing over 30 % followed by China 21 % and Brazil 7.9 %. Africa produces around 7 % of the total world production. Two-thirds of all Africa maize come from eastern and southern Africa (Verheye, 2010 and FAOSTAT, 2014). In sub-Saharan Africa, (SSA) maize is the most important cereal crop and staple food. The total quantity of maize produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. Storage is a way or process by which agricultural products or produce are kept for future use". (Nukenine, 2010), during storage there are developments of molds and insect infestation that can reduce the quality of stored product (Maier *et al.,* 1996). Fluctuations in temperature, humidity and prolonged storage duration result in considerable nutrient losses (Shah *et al*., 2002). The allowable storage time for maize is the time until 0.5 % of dry matter decomposition is reached (Hellevang, 2005). The purpose of storage is to maintain harvest quality of product, not to improve it (Sisman and Delibas, 2004) storage has direct relationship with quality of seed which means if the product is stored under well-organized storage condition the quality of the seed may not affected or may the level of deterioration be minimize. It is found that significant differences in germination and seed vigor among 10 inbred lines with different composition and genetic backgrounds (Munamava *et al.*, 2004). It was reported that the membranes of aged seeds, whose integrity has been reduced by deterioration, are more susceptible to the physical damage such as imbibition damage resulting from rapid imbibition and then yield reduction. The seeds will have low vigor due to ageing during storage will be more likely to

have poor field emergence (Powell, 1998). The variability in seeds of maize inbred lines for germination, quality and yield under certain storage duration was reported. However, information is scanty about the effect of storage duration on seed yield of maize inbred lines in Ethiopia. This research was therefore proposed with the objective of evaluating effects of storage duration on seed yield and yield related traits of maize inbred lines.

2. MATERIAL AND METHODS

2.1 Descriptions of Experimental Site

The experiment was conducted at Bako National Maize Research Center (BNMRC), during 2017 main cropping season. The area is located in East Wollega Zone of the Oromia National Regional State, Western Ethiopia. The Center lies between 906' North latitude and 37009' east longitude in the sub-humid agro-ecology, at average altitude of 1650 meters above sea level (m.a.s.l). It is 250 km far from Addis Ababa, the capital city of the country. The mean annual rainfall of the area is 1242 mm (BNMRC, 2015). The rainy season covers April to October and maximum rain is received in the months of July and August. The mean minimum, maximum and average air temperature is 13.3, 28.0, and 20.6 0C, respectively; and the relative humidity is 63.55%. The soil is reddish brown in color and clay loam in texture. According to USDA soil classification, the soil is Nitosols developed from basalt parent materials, and is deeply weathered and slightly acidic in reaction (Wakene, 2001). The laboratory and pot experiments were also conducted at Bako agricultural research center (BARC) seed testing laboratory.

2.2. Experimental Materials

The seed of five inbred lines which were harvested from reddish brown soil of Bako National Maize Research Center seed production field in 2014,2015,2016 main rainy seasons and stored under uniform storage condition. Therefore, (5 inbred lines x 3 storage periods) treatments in factorial combination were produced. The inbred lines were selected based on availability of their seed in the storage (Table-1).

Table 1: List of inbred lines, year of harvest and storage period

Year of harvest	CML395	CML202	CML312	CML165	A-7033
2014	29 month	29 month	29 month	29 month	29 month
2015	17 month	17 month	17 month	17 month	17 month
2016	5month	5month	5month	5month	5month
source	CIMMTY	CIMMTY	CIMMTY	CIMMTY	BNMRC

CIMMTY = Centro Internacional de Mejoramiento de Maiz y Trigo
BNMRC = Bako National Maize Research Centre.

2.4. Data Collection

2.4.1. Yield and Yield Related Traits

2.4.1. 1. Data collection on a plot basis

Days to anthesis: The number of days from 50% of emergence to when 50% of the plants in a plot start shedding pollens.

Days to silking: The number of days from 50% of plant emergence to when 50%of the plants in a plot have grown 2-3 cm long silks.

Days to physiological maturity: The number of days from 50% of emergence to when 50% of the plants in a plot form black layer at the tip of the kernel.

Number of ears per plant: The total number of ears selected for selfing on individual plant in each plot.

Number of seeds per plant: This was recorded before bulking the seed of each selected ears from each plant in each plot. The seed of sampled ear from each selected individual plant in the plot was counted.

Grain weight per plot: bulk of shelled grain from each plot was measured and recorded.

Seed yield per plant (g): This was recorded by dividing weight of grain per plot measured above for number of plant in which ears was harvested.

Disease score: Major diseases at the experimental site [Gray leaf spot (GLS), Turcicum leaf blight (TLB), Common leaf rust (CLR) and pheosphorea (PLS)] was recorded using 1-5 visual scale, where 1 indicate highly resistant and 5 highly susceptible in terms of reaction to the particular disease to be assessed three weeks after flowering before the green color of leaves are become too dry.

Plant aspects: was recorded on a 1 to 5 scale, where 1 means the best variety (considering general appeal of the plants per row: plant vigor, ear size, ear placement (not to high not too low), good husk cover, uniformity, disease infestation, and so on) while 5 means the worst plant aspect.

Ear aspect: was recorded on a 1 to 5 scale where 1 refers to the best ear aspect (considering general appeal of the ears: ear size, uniformity bare tipness (whether the grain filled up to the tip of the ear, kernel row arrangement, ear rot infection and other acceptable characters) while 5 refers to the poorest ear aspect with undesirable characteristics.

2.4.1.2. Data collected on sampled plants/ears basis

Ten plants or ears was randomly sampled from each experimental unit and the required measurements for each parameter was recorded from each plant/ear; then the mean values of each sample were calculated for data analysis. The data that was collected are:

Ear length (cm): Length of the ear from the base to tip of the ear. It was measured as the average length of 10 randomly taken ears from each experimental unit.

Ear diameter (cm): This was measured on each ear of the same samples used for ear length measurement, at the mid-way along ear length.

Number of rows per ear: This was recorded as the average number of kernel rows per ear, counted from each of the randomly taken ear samples.

2.4.1.3. Data collected on disease parameters

All the most maize disease like grey leaf spotr, Turcicum leaf blight poesphorea and common leaf rust was recorded based on visual observation by the scale evaluation.

2.5. Data Analysis

2.5.1. Analysis of variance

Analysis of variance (ANOVA) for all data was computed as per the design used in each experiment was carried out to determine the presence of significance differences among the genotypes using ANOVA procedure of SAS 9.1 software computer program. Significant differences were further subjected to Duncan's new multiple range test (DMPR) and Mean separation was carried out using LSD at 5% probability level and correlation coefficients was also calculated.

3. Result and discussion

3.1. Crop Phenology

The days to anthesis and silking were significantly influenced by the variation of inbred lines but not by seeds storage duration and the interaction of storage duration and inbred lines. Days to physiological maturity was influenced neither by the two main factors nor the interaction of the two factors.

The inbred line CML165 attained anthesis and silking significantly late, while A-7033 required short period to attain anthesis and silking which was significantly different from other inbred lines. However, the differences between the late and early inbred lines were at about seven and eight day's anthesis and silking, respectively. CML312 had anthesis date non-significant different from CML395 and CML202 but it had silking date significantly different from the two inbred lines. The two inbred lines (CML395 and CML202) showed significant difference for days to anthesis but not for days to silking (Table 2). The results suggested the inbred lines had not many differences for days to anthesis and silking and seeds storage duration had not significant effect on the days of anthesis and silking. The results of this study might be supported by the findings of (Donmez et al., (2001) from winter wheat, Teshager *et al*., (2016) and Kibebew (2001), from tef that the differences for flowering and maturity among improved varieties are mainly due to the genetic differences.

Table-2. Variations among five maize inbred lines for days to anthesis and silking evaluated at Bako in 2017 cropping season

Inbred lines	Anthesis date	Silking date
CML395	86.67^{c}	87.44^{c}
CML202	88.89^{b}	89^{bc}
CML312	88.56^{bc}	89.89^{b}
A7033	84.22^{d}	84.67^{d}
CML165	91.44^{a}	92.33^{a}
LSD (5%)	1.963	2.363
Mean	87.96	88.67
Storage duration (Month)		
5	87.33	88.13
17	87.8	88.53

29	88.73	89.33
LSD (5%)	NS	NS
Mean	87.96	88.67

Mean values followed by the same letter(s) in column of each trait had non-significant difference each other at 5% probability level. LSD (5%) =least significant difference at P<0.05.

3. 2. Growth Traits

The growth traits of maize (plant height, ear aspect, ear height, ear length and ear diameter) was significantly influenced by variation of inbred lines but nor by seeds storage duration and neither the interaction of two main effects. However, plant aspect was significantly affected by seeds storage duration, inbred lines and the interaction of storage duration and inbred lines.

Seed sample of A-7033 had higher plant height significantly different from the mean of other treatment combinations. Over all mean of plant height was ranged between 185.6cm and 151.3cm. However all treatment combinations except line A-7033 had no significant differences for plant height with each other's. CML165 had the higher mean of ear aspect significantly different from other treatments while the seed samples of CML395 and CML312 had the lower means. The higher mean (2.61) for ear aspects was registered for seed sample of line CML165 while the lower mean (1.17) was registered from CML395. This indicated that the higher mean value for line CML165 was bad performance of ear aspect while the lower means showed the better performances of ear aspect (Table-3). The value of plant and ear aspect during evaluation greater and equal to 2.5 in number was indicated the poor performance while the small number was indicated good performances. Thus, in this studies ear aspects of line CML165 had poor performance and line CML395 had better performances all over the others.

Regarding ear length the seed samples of CML395 followed by CML312 had higher means without differences among two lines but had significant different from mean of other treatment combinations. While the seed sample of line CML165 had the lower mean of ear length. Ear length might be special criteria to guess seed yield per ear and per plant as it has been observed in current results, the higher ear length and seed yield per plant was obtained from similar line. CML395 was registered the higher mean for ear diameter significantly different from the mean of other treatment combinations while the lowest mean was registered from CML165. In the current experiments genotype variances of maize inbred lines highly influenced all ear characteristics parameters. As been documented by Kibebew (2001) varietal variation was highly influenced plant height of tef. Ear characteristics might be affected the overall yields of maize in which Samavia et al., (2017) was suggested that plant height and ear height was an important trait which affected the overall grain yield of the crops.

Table-3. Variations among five maize inbred lines for growth traits evaluated at Bako in 2017 cropping season

Inbred line	Plant height(cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Ear aspect
A- 7033	185.6^{a}	96.76^{a}	39.84^{bc}	4.889^{bc}	1.944^{bc}
CML 165	151.3^{b}	70.58^{c}	33.15^{d}	4.468^{d}	2.61^{a}
CML312	160.2^{b}	81.94^{b}	42.73^{ab}	5.203^{b}	1.61^{c}
CML 395	156.3^{b}	82.94^{b}	44.9^{a}	5.856^{a}	1.17^{c}
CML202	160b	67.4^{c}	37.83^{c}	4.644^{cd}	2.11^{b}
LSD (5%)	11.002	9.339	3.76	0.409	0.444
Mean	162.68	79.92	39.69	5.01	1.98

Mean values followed by the same letter(s) in column of each trait had non-significant difference each other at 5% probability level. LSD (5%) =least significant difference at P<0.05.

Seed sample of CML165 grown from 29months stored seed had higher plant aspect significantly different from the means of other treatment combinations. While the seed sample of CML395 grown from seed stored for five months had lower mean. The higher mean was registered from seeds grown from CML165 (2.06) and line A-7033 (2.0) without significant different between the two lines but had significant different from other treatment combinations and the lower mean (1.28) was registered from seed of CML395. Seed samples grown from 29months stored seed had highest mean whereas seeds from 5 and 17months stored seed had the lower means with no significant differences among them. As explained above in ear aspect parameters, the lower values of maize inbred lines for plant aspects was also showed better performances of that line while the inverse is true for that of higher means. Interaction of inbred lines and storage

duration and the two main factors was significantly affect plant aspects parameter in current study however, information is scantly on the effects of storage duration and inbred line on plant aspects of maize respectively.

Table-4. Interaction effect storage duration and inbred lines on plant aspect of maize evaluated at Bako in 2017 cropping season

Inbred line*Storage duration (month)	Plant aspect			
	5	17	29	Inbred lines
CML395	1^{f}	1.33^{def}	1.5^{cdef}	1.28^{c}
CML202	2^{cd}	1.5^{cdef}	1.167^{ef}	1.56^{b}
CML312	1.33^{def}	1.5^{cdef}	2.83^{ab}	1.89^{ab}
A7033	2^{cd}	2.167^{c}	1.83^{cde}	2^{a}
CML165	1.5^{cdef}	1.5^{c-f}	3.16^{a}	2.06^{a}
LSD (5%)		0.445		
Overall mean		1.76		
Storage duration	1.567^{b}	1.6^{b}	2.1^{a}	
LSD (5%)		0.345		

Mean values followed by the same letter(s) in columns and rows in the interaction of Inbred line*Storage duration, column and row of mean values of inbred line and storage duration, respectively, had non-significant difference at 5% probability level. LSD (5%) =least significant difference at $P<0.05$.

3. 3. Yield Components

The interaction of storage duration and inbred line and the two main effects had significant effect on number of ear per plant and number of seed per ear. Genotype variation of maize inbred lines was affected number of rows per ear while the interaction of the two main effects and storage duration had no significant difference on this trait.

The sample seed of CML395 grown from five months stored seed had higher number of seed per ear significantly different from the mean of other treatment combinations. On the other hand, seed sample of CML165 grown from seed stored for 29months had lower mean. The highest mean (297.22g) number of seed per ear was registered from seed of line CML395 while the lower means of number of seed per ear was registered form seed samples of CML165 (198.63g), CML202 (214.44g) and CML312(217.1g) with no significant differences between the three lines. Seeds grown from 5 and 17months stored seed had higher number of seed per ear significantly different from seed grown from 29months stored seed respectively.

Regarding number of ears per plant seed samples of CML395 and CML202 grown from seed stored for five months, A-7033 grown from seed stored for all duration had the higher mean without differences between each other and significantly different from other treatment combinations. On the other hands the seed samples of CML312 grown from seed stored for all durations (5, 17 and 29months), CML395 grown from seed stored for 17 and 29 months followed by CML165 grown from 29 months stored seed had the lower mean for number of ear per plant. The highest mean (2) was registered from seed of line A-7033 and the lowest mean (1) was from seed of line CML312. Seeds grown from five months stored seed had higher number of ear per plant while seed grown from 29months stored seed had the lower mean. Seed sample of CML395 grown from five months stored seed had higher mean for both traits (number of seed per ear and number of ear per plant) and CML165 grown from 29months stored seed had the lower means for the traits respectively (Table -5). Thus extended of storage period of maize inbred lines was produce the lower number of seed per ear and number of ear per plants.

Table-5. Interaction effect storage duration and inbred lines on number of ear per plant and number of seed per ear of maize evaluated at Bako in 2017 cropping season

	Number of seed per ear				number of ear per plant			
Inbred line*Storage duration (month)	5	17	29	Inbred lines	5	17	29	Inbred lines
CML395	349^{a}	301.3^{b}	241.3^{cd}	297.22^{a}	2^{a}	1c	1^{c}	1.33^{bc}
CML202	204.7^{def}	235.3^{cd}	203.3^{def}	214.44^{c}	2^{a}	1.67^{ab}	1^{c}	1.556^{b}
CML312	219.3^{cde}	212.7^{cde}	219.3^{cde}	217.1^{c1}	1^{c}	1^{c}	1^{c}	1^{d}
A7033	233.7^{cd}	246.7^{c}	246.6^{c}	242.3^{b}	2^{a}	2^{a}	2^{a}	2^{a}
CML165	231.6^{cde}	192.3^{ef}	172^{f}	198.63^{c}	1.33^{bc}	1.33^{bc}	1^{c}	1.22^{cd}
LSD (5%)		22.7				0.237		
Overall mean		233.94				1.42		
Storage duration	247.7^{a}	237.7^{a}	216.5^{b}		1.667^{a}	1.46^{b}	1.2^{c}	
LSD (5%)		17.585				0.84		

Mean values followed by the same letter(s) in columns and rows in the interaction of Inbred line*Storage duration and column of mean values of inbred line had non-significant difference at 5% probability level. LSD (5%) =least significant difference at P<0.05.

Seed samples of CML312 followed by CML395 had higher number of rows per ear significantly different from means of other treatment combinations. Whereas seed samples of line CML202 and 165 had the lower mean for number of rows per ear. Genotype variation had little affect on this parameters and storage duration and the interaction of the two main factors had no significant effects on number of rows per ear respectively.

Table-6. Variations among five maize inbred lines for number of rows per ear evaluated at Bako in 2017 cropping season

Inbred lines	Number of rows per ear
CML312	14.89^{a}
CML395	14.44^{ab}
A-7033	13.11^{bc}
CML165	12.44^{c}
CML202	12.22^{c}
LSD (5%)	1.535
Mean	13.42

Mean values followed by the same letter(s) had non-significant difference each other at 5% probability level. LSD (5%) =least significant difference at P<0.05.

3.3.1. Seed Yield

Inbred lines and storage duration and their interaction was significantly influenced grain weight per plot and seed yield per plant. The results indicated seed sample of CML395 grown from seed stored for five months had higher grain weight per plot significantly different from mean of other treatment combinations. While seed samples of CML165 and CML312 grown from seed stored for 29months had lower mean values. The highest mean (859.56g) grain weight per plot was registered from line CML395 while the lowest mean (320.78g) was registered from line CML165. The mean value of line CML395 over all storage durations was good as compared with the others, while mean value of line CML165 was lowest for seed grown from all storage durations. Generally, the maximum mean values were registered by seed grown from five months stored seed and the minimum mean was registered from seed stored for 29months for different treatment. This indicated that storage duration, genotypic variation and the interaction of two main effects was highly influenced amount of grain weight per plot obtained from different maize inbred lines.

Seed sample of CML312 grown from seed stored for five month had higher seed yield per plant significantly different from mean of other treatment combinations. On the other hands seed sample of CML165 grown from 17 and 29months stored seed had lower mean. The higher mean value (57.17) was registered from seed of line CML395 while the smaller

(33.9) mean value was registered from seed of CML165 (Table-7). The results of seed yield per plant for maize inbred line showed reduction at seed grown from beyond five months stored seed. Thereby highest mean for this trait was registered by seed grown from five months stored seed whereas the lower mean was registered by seed grown from 29month stored seed respectively. Therefore, seed yield per plant significantly affected when the storage duration was prolonged. The highest mean for both grain weight per plot and seed yield per plant was registered for seed grown from five months stored seed, while the lower mean for both traits was registered from plant grown 29months stored seed. Generally inbred lines, different duration and interaction of the two main effects was significantly influence these two important yield traits. This finding might be supported by (Hussain et al., 2015), as explained reduction of seed yields by higher temperatures and longer storage durations of non-primed seed and (Chiu et al., 2002), decrease growth and yields of sweet corn seed by length of storage periods.

Table-7. Interaction effect storage duration and inbred lines on grain weight per plot and seed yield of maize evaluated at Bako in 2017 cropping season

Inbred line*storage duration	Grain weight per plot (g)				Seed yield per plant (g)			
	5	17	29	Inbred lines	5	17	29	Inbred lines
CML395	892^{a}	855.3^{b}	831.3^{b}	859.56^{a}	60.23^{ab}	58.63^{bc}	52.64^{bc}	57.17^{a}
CML202	422.7^{g}	543.3^{e}	493.3^{f}	486.44^{d}	34.99^{ef}	36.92^{d-f}	31.3^{fg}	34.4^{d}
CML312	839.3^{b}	483.3^{f}	222^{i}	514.89^{c}	67.83^{a}	40.73^{de}	41.66^{de}	50.07^{b}
A7033	573.3^{d}	636^{c}	586.7^{d}	598.67^{b}	43.08^{d}	44.23^{d}	34.82^{ef}	40.71^{c}
CML165	414.7^{g}	321^{h}	226.7^{i}	320.78^{e}	52.18^{c}	24.19^{g}	25.34^{g}	33.9^{d}
LSD (5%)		16.478				2.154		
Overall mean		556.07				43.25		
Storage duration	628.4^{a}	567.8^{b}	472^{c}		51.66^{a}	40.94^{b}	37.15^{c}	
LSD (5%)		12.764				3.417		

Mean values followed by the same letter(s) in columns and rows in the interaction of Inbred line*Storage duration, column and row of mean values of inbred line and storage duration, respectively, had non-significant difference at 5% probability level. IL= inbred line and LSD (5%) =least significant difference at P<0.05.

3.4. Disease Parameters

Maize inbred lines had significant effect on different maize foliar disease while storage duration and the interaction effect of the two main factors had no significant effects on disease parameters For all maize foliar disease inbred line A-7033 was highly susceptible than other treatment combinations while seed sample of CML395 had higher resistance to all disease except for common leaf rust disease. All treatment combination was equally resisted to common leaf rust disease except seed of A-7033 inbred line. The level of resistance or susceptibility of maize inbred lines was depend on ability of that plant to defend the disease which was connected to gene that governed the races of disease. As it has been observed in current experiments the gene of line A-7033 had less defensive mechanism to races of all disease since it was susceptible as compared to other inbred lines. However common leaf rust and phoesporea was highly severe on this line as compared to other disease since severity level was above 2.5 in number, though all inbred line for all disease had more or less not highly influenced because they registered below the level of severity for all disease. Information was very lacking about the effects of genotype variation on maize foliar disease. However (Samavia*et al*., 2017) observed significant effect of southern corn leaf blight on different genotypes of maize pathological parameters and yields. This might be in line with current results respectively.

Table 8. Effect of genotype variation on maize foliar disease of inbred lines

Inbred Lines	Grey leaf Spot	Turcicum leaf blight	Phoesporea	Common leaf rust
A-7033	1.889a	1.94a	2.889a	3.167a
CML202	1.5b	1.72b	2.389b	2.278b
CML165	1.389bc	1.61c	2.222b	2.333b
CML312	1.333bc	1.89ab	1.833c	2.167b
CML395	1.167c	1.72b	1.667c	2.056b
LSD (5%)	0.288	0.274	0.26	0.389
Mean	1.46	1.78	2.2	2.4

Means in column of each maize foliar disease parameter followed by the same letter(s) are not significantly different from each other at 5% probability level. LSD (5%) =least significant difference at P<0.05.

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CITATION
Elsabet B. (2025). Effect of Seed Storage Duration on Seed Yield and Yield Related Traits of Maize Inbred Lines. In Global Journal of Research in Agriculture & Life Sciences (Vol. 5, Number 3, pp. 32–39).
https://doi.org/10.5281/zenodo.15491813