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Correlations Between Physical and Physiological Quality Traits in Mutant and Non-Mutant UNPAD Sweet Corn Seeds After 4 Months Storage

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***Abstract*—Seed longevity could be described as a measure of seed viability after being stored for a certain period under particular conditions. Viability may vary due to genetic factors. The variations can be evaluated using physical and physiological quality traits such as seed weight, viability, and vigour. The results of such an evaluation are useful for future breeding efforts to enhance existing cultivars and develop new ones. We evaluated the physical and physiological traits of sixteen genetic lines randomly selected according to seed weight variations between mutated and non-mutated populations in UNPAD maize collections. The experimental design in this study was conducted using randomized completely design, with two replications. The data were analysed using analysis of variance and if data was significant then the post-hoc tested used Scott-Knott and Duncan at 5% level. Besides, we calculated the correlation between physical and physiological quality traits of seed. The results showed that the variation was exist in UNPAD maize collections. Furthermore, correlation analysis revealed that the positive and significant correlation between seed weight and synchrony of seed germination after 4 month storage. We suggested that seed weight was important traits for breeding program in maize to select good quality in associated to seed longevity.**

***Keywords*— seed quality, seed size, sweet corn**

I. INTRODUCTION

Sweet corn (*Zea mays* L. var. saccharata) is one of the most popular vegetables in Indonesia because it can be consumed as a fresh vegetable or as part of processed products, and it has high sugar content. In Indonesia, the consumption of sweet corn has increased year after year while production has dropped with reference to the theoretical yield potential. The high demand for this crop necessitates improvements to crop production.

One of the potential ways to optimize the yield of sweet corn is to use high quality seed. Erker [1] suggested that high quality seed could improve the yield of the sweet corn crop more than other any input. A similar recommendation has been made with reference to wheat cultivation after research that concluded that poor quality seed had a negative impact on wheat yield [2] Seed quality can be evaluated using genetic, physical, and physiological characteristics. High seed quality is reflected by high rankings in these factors [3] However, breeders are not especially interested in breeding cultivars for seed quality. Their breeding programs focus on developing high-yield cultivars [4].

Universitas Padjadjaran's (UNPAD's) maize enhancement program has created hundreds of new breeding lines since 2000. Several studies of variations have been conducted using molecular tools and observations of agro-morphological traits [5], [6]. The projects used conventional and modern techniques including irradiation to create cultivars of field and sweet corn. The notation for irradiated germ lines that were irradiated uses M codes such as "MDR" and "MSR" [7], However, the seed quality of these lines was never evaluated. In general, physiological qualities such as large seed size correlate with higher seed quality [8], [9], and [10].

The qualities of seed deteriorate during storage for reasons aside from genetic quality. In open storage, usually seed moisture content has fluctuated and it caused changes in seed quality. Raising the moisture content of seed to a certain level can affect to the physical and physiological quality of seed. Harrington [11] suggested that increasing the humidity in the storage environment can increase the rate of seed deterioration and correspondingly decrease the average seed germination rate and vigour after storage. Marques [12] reported that natural storage conditions caused several cultivars with low physiological quality traits to deteriorate, and only one rice cultivar met the minimum requirements for commercialization after 6 months in storage. Therefore, to optimize the maize breeding program, it is essential to assess seed quality of the sweet corn lines in the UNPAD maize collection before developing them as future profitable breeding materials.

The aims of our study were to evaluate variations in the seed quality of 16 lines derived from randomly selected inbred UNPAD sweet corn lines and categorized according to their mutation-non mutation lines and seed weight arrangements. Besides, to determine correlation among seed quality traits using open storage treatment. We tested seed quality traits using open storage treatment.

II. METHODS

This study was conducted in Plant Breeding and Seed Technology Laboratory of Faculty of Agriculture Universitas Padjadjaran (UNPAD) from July 2017 to January 2018.

A. Seed materials

The Laboratory of Plant Breeding and Seed Technology of Universitas Padjadjaran, Indonesia provided seeds of 16 mutated and non-mutated lines. The seed weight arrangement was examined using PCA (Principal Component Analysis) because there are few to no studies suggesting classifications of seed size in sweet corn (Table 2). The seed was packaged using porous pack (fabric) and stored in ventilated boxes. Temperature and relative humidity readings were collected from digital thermo-hygrometers every day during the storage period (Table 1).

Table 1. Temperature and relative humidity during seed storage

Month	Observation	
	Temperature (°C) (Standar error)	*Relative humidity (%) (Standar error)*
1st	25.7 (0.81)	64.2 (1.86)
2nd	25.1 (0.77)	61.4 (1.88)
3rd	26.3 (0.82)	56.0 (2.57)
4th	24.8 (0.65)	64.0 (1.12)
Mean	25.0	63.7

B. Seed Quality Measurement

The quality of seed was measured as described by ISTA (International Seed Testing Association) and a modification formula reported by several researchers. We checked the quality of seed before and two times after storage period (2 and 4 month). The physical qualities measured were the moisture content and seed weight per 100 seeds. Following ISTA's oven method, we exposed samples to a temperature of 130ºC for 36 hours to obtain moisture content measurements, and measured seed weight per 100 seeds. Moisture content and seed weight are the important traits in maize, as described by [13]. The physiological qualities measured in this study were seed germination capacity and the synchrony of seed germination. Seed germination tests were conducted using paper rolls in a solar germinator at room temperature, and germinated seeds were counted at four and seven days [14], [15], and [16]. The synchrony of seed germination was calculated from the percentage of normally germinated seed at four days.

C. Statistical Analysis

The experiment was conducted using a simple completely randomized design with two replications on 16 lines, as described above. The data were calculated using analysis of variance (ANOVA) and continued with two kinds of averaging tests, Scott-Knotts [17] and Duncan tests at a 5% level [18] using SASM Agri 3.2.4 [19]. Correlations were analysed using SPSS 24

III. RESULTS AND DISCUSSION

The variations within UNPAD sweet corn lines can divided into two group (un-shown (PCA)). Lines with average seed weights above 12.35 g were placed in the large seed group and those below 12.35 g were placed in the small seed group. The seeds were then distributed into mutation and non-mutation groups. According to the seed quality data collected before storage, the seeds in each line in this study were of good quality (Table 2), as shown by seed germination capacity. All of the tested lines had germination rates above >80% and seed germination synchrony above 40% [20].

Table 2. Quality of UNPAD sweet corn seed before storage

Lines	Seed Quality Parameters			
	Seed Moisture content (%)	*100 Seed weight (g)*	*Seed germination capacity (%)*	*Synchrony of seed germination (%)*
533 (MSR)	14.64	16.39	90.00	75.00
769 (MSR)	14.80	12.39	90.00	70.00
820 (MSR)	14.61	10.44	93.75	48.75
871 (MSR)	14.19	9.51	95.00	50.00
896 (MSR)	13.60	12.52	92.50	62.50
981 (MSR)	14.50	11.60	87.50	67.50
987 (MSR)	14.74	9.92	96.25	82.50
992 (MSR)	13.93	11.62	93.75	77.50
994 (MSR)	14.57	13.32	86.25	56.25
774 (SR)	13.95	11.52	86.25	52.50
785 (SR)	14.43	12.35	92.50	82.50
793 (SR)	14.14	13.53	92.50	76.25
824 (SR)	14.17	11.84	87.50	65.00
849 (SR)	13.74	10.18	92.50	52.50
857 (SR)	13.96	10.89	91.25	75.00
858 (SR)	14.00	10.31	92.50	53.75

The results of ANOVA showed significant values in both the Scott-Knott and Duncan tests at 5% seed moisture content levels after 4 months of storage. We found significant results in measurements of seed weights after 2 and 4 months of storage, seed germination capacity after 4 months of storage, and seed germination synchrony after 2 and 4 months of storage (Tables 3 and 4). The results indicate that the quality of seed was influenced by environmental conditions. Fluctuations of temperature and relative humidity affected the moisture content of the seed and lowered its quality. The reductions in quality manifested in changes in the physiological traits of the seed, namely low seed germination rates and after 4 months of storage.

McDonald [21] reported that seed moisture content can change in sync with the external temperature and relative humidity, eventually reaching what is called "seed equilibrium moisture". In this study, we found that the moisture content of seed increased by about 2% over 4 months of storage, as seen at Table 3. This condition could affect to physiological quality of seed.

Table 3.Seed physical quality traits in UNPAD sweet corn maize after storage

Lines	Seed Moisture Content (%)		100 Seed Weight (g)	
	2 month after storage[1]	*4 month after storage[2]*	*2 month after storage[1]*	*4 month after storage[1]*
533 (MSR)	11.33 a	13.46 ab	15.25 a	15.68 a
769 (MSR)	11.04 a	13.38 ab	11.49 e	11.42 c
820 (MSR)	11.81 a	13.58 ab	9.79 h	9.41 e
871 (MSR)	11.25 a	13.40 ab	9.09 i	9.56 e
896 (MSR)	11.17 a	13.93 ab	12,22 d	11.91 c
981 (MSR)	11.11 a	13.28 ab	11.46 e	11.39 c
987 (MSR)	11.42 a	11.81 c	9.16 i	9.33 e
992 (MSR)	10.91 a	13.74 ab	10.89 f	11.20 c
994 (MSR)	10.22 a	13.44 ab	12.58 c	13.17 b
774 (SR)	11.09 a	13.91 ab	11.42 e	11.69 c
785 (SR)	11.04 a	13.15 b	12.18 d	11.73 c

793 (SR)	11.55 a	13.19 b	13.00 b	13.15 b
824 (SR)	11.20 a	13.43 ab	11.46 e	11.44 c
849 (SR)	11.98 a	14.31 a	9.65 h	8.63 e
857 (SR)	11.26 a	13.43 ab	10.86 f	10.51 d
858 (SR)	10.89 a	13.28 ab	10.23 g	9.45 e

Note: Means followed by the same letter indicate insignificant differences within each column.
1Using Scott-Knott's test at a 5% moisture level and 2 using the Duncan test at a 5% moisture level

The results showed that seed germination capability (total germination at the last count (7 days)) and the synchrony of seed germination at the fourth day decreases over time. However, 5 of 16 lines still presented good physiological performance defined as seed germination rates >80% after 4 months of storage. The decreasing physiological quality of the seed was revealed by decreased synchrony of seed germination in all of the tested lines after 4 months of storage. While, the line number 994 had synchrony of germination rates was below 40%. Harrington discovered that increases of one percent in moisture content and 5 ºC in temperature halve the longevity of seed [11].

We also found that the *Sitophilus zeamais* “weevil” can do serious damage to seed maize over 4 months of storage. The correlation between the physical and physiological quality traits of seed was not statistically significant after 2 months of storage. However, we found significant correlations between seed weight and rate of germination synchrony after 4 months of storage (Table 5). These results indicate that weighty seed has better longevity than light seed. One possible reason for this effect was that larger seeds have larger amounts of energy stored in their cotyledons than small seeds. [22] reported that seed size correlates with cotyledon size, and a larger cotyledon represents a larger energy reserve than a small one. High germination synchrony demonstrates good energy storage characteristics (4 days count).

Table 4. Seed physiological parameters in UNPAD sweet corn maize after storage

Lines	Seed Germination Capacity (%)		Synchrony of Seed Germination (%)	
	2 month after storage[1]	*4 month after storage*[2]	*2 month after storage*[1]	*4 month after storage*[1]
533 (MSR)	90.00 a	81.25 ab	35.00 b	36.25 a
769 (MSR)	87.50 a	75.00 abcd	63.75 a	28.75 a
820 (MSR)	92.50 a	75.00 abcd	71.25 a	3.75 c
871 (MSR)	97.50 a	88.75 a	72.50 a	20.00 a
896 (MSR)	92.50 a	68.75 bcd	50.00 b	8.75 b
981 (MSR)	93.75 a	83.75 ab	41.25 b	15.00 b
987 (MSR)	97.50 a	75.00 abcd	82.50 a	21.25 a
992 (MSR)	78.75 a	61.25 d	56.11 b	27.50 a
994 (MSR)	78.75 a	81.25 ab	66.25 a	41.25 a
774 (SR)	95.00 a	70.00 bcd	50.00 b	2.50 c
785 (SR)	93.75 a	72.50 abcd	71.25 a	32.50 a
793 (SR)	91.25 a	85.00 ab	74.86 a	36.25 a
824 (SR)	96.25 a	78.75 abc	70.00 a	13.75 b
849 (SR)	91.25 a	62.50 cd	66.25 a	1.25 c
857 (SR)	83.75 a	78.75 abc	31.25 b	7.50 b
858 (SR)	96.25 a	63.75 cd	53.75 b	8.75 b

Note: Means followed by the same letter indicate insignificant differences within each column.
1Using Scott-Knott's test at a 5% moisture level and 2 using the Duncan test at a 5% moisture level

Table5. Coefficient of correlation between seed mass and seed quality parameters

		Seed Quality Parameters		
	Times	*Seed moisture content*	*Seed germination capacity*	*Synchrony of seed germination*
seed mass	Before storage	0.364	-0.433	0.376
	2 month storage	0.279	0.262	0.109
	4 month storage	0.064	0.365	0.668**

Note: ** = correlation is significant at the 0.01 level (2 tailed)

IV. CONCLUSION

Variations in the quality of seed in UNPAD sweet corn lines was revealed by physical and physiological traits in this study. There is a significant correlation between physical and physiological traits in relationship to the longevity of seed.

Seed size was a measure of energy reserves and larger energy reserves allow a seed to withstand long periods of storage. Seed germination synchrony was a useful parameter to measure the longevity of seed and. alongside seed size could help seed breeders develop improved cultivars.

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