Preliminary Identification of Local Maize Under Drought Stress By PEG-6000

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Abstract. Adaptation test of local maize plants under drought stress requires early selection at the seedlings stage through Poly Ethylene Glycol (PEG-6000). This study aimed to identify local varieties of maize plants from North Sumatra under drought stress with several doses of PEG-6000. This study was conducted from July to November 2022 using a completely randomized design with two factors and three replications. The sixteen local maize (L) and a hybrid variety (H) of maize as a comparison were used as the first factor. The PEG doses were 0; 100; 200; 300; 400; and 500 g L^{-1} as the second factor. Data were analyzed using analysis of variance and duncan's multiple range test at $P<0.05$. The results showed that the LSB5 and LSB4 of local maize from Serdang Bedagai had the greatest number of seeds germinated and water content of seedlings at 40.17 seeds and 74.43%, respectively. The higher PEG dose of 500 g L^{-1} inhibited the number of seeds germinated and water content of local maize seedlings to 32.27 and 11.45%, respectively. The interaction of local varieties with PEG doses were insignificant effects on both characteristics of local maize.
Keywords: drought stress; local maize; PEG doses; water content

1 Introduction

The phenomena of maize farmers adopting locally derived seeds for subsequent cropping activities leads to a decrease in national maize yields. Data from [1] reported that local maize cultivation in Indonesia covers 4.4 million ha or 41%. On the other hand, the farmers prefer local seed varieties because the price of hybrid seeds is more expensive and their availability was limited [2]. Although local maize yields are lower, flowering and harvesting ages are more rapidly compared to a hybrid variety [3]. Another reported phenomenon that caused low maize yields was climate change. [4] said the phenomena of climate and seasonal changes are disadvantageous to cultivated crops. [5] added that the impact of

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climate change was associated with drought intensity. [6] found that drought stress caused maize yield losses ranging from 40-65% depending on genotypes/varieties, plant growth stages, and drought stress intensities.

Both of these phenomena contribute to a decrease in maize yields, which requires mitigation efforts. The first effort was to identify the level of drought tolerance in the seedling stage by applying chemicals. The seedling stage was selected due to its being more sensitive than the vegetative stage [6]. In general, the recommended chemical for preliminary drought stress screening involves Poly Ethylene Glycol (PEG) 6000. PEG-6000 was preferred because the ingredients are non-absorbed by plants and are not affected by toxicity [7]. It has been verified to use PEG-6000 as a medium in the identification of local maize for drought stress in the seedling stage from Nepal [8] and Madura, Indonesia [9]. [10] found that increasing the PEG dose to 10% inhibited the percentage germination of maize. However, local maize from North Sumatra has never been identified on drought stress in the seedling stage. The study aimed to identify local maize varieties from North Sumatra on drought stress in the seedling stage, especially the number of seeds germinated and total water content.

2 Material and methods

The collection of local maize (L) seeds refers to [11] from 4 districts/cities in North Sumatra. A total of 16 local maize seed collection locations from Binjai (LB1, LB2, LB3), Serdang Bedagai (LSB1, LSB2, LSB3, LSB4, LSB5), Deli Serdang (LDS1, LDS2, LDS3, LDS4, LDS5), and Mandailing Natal (LMN1, LMN2, LMN3), North Sumatra Province, Indonesia, as well as a hybrid variety (H) of BISI-79 was selected for comparison. Physiologically mature maize cobs were harvested and dried to 14% water content. This study was conducted from July to November 2022 with a factorial completely randomized design and three replications. The first factor was hybrid and local varieties while the second factor was the PEG-6000 dosage, i.e. 0, 100, 200, 300, 400, and 500 g L-1 aquadest.

Weighed PEG-6000 according to the treatment and dissolved with a liter of aquadest until homogeneous. Watered the PEG solution on filter paper until moist then sowed 50 seeds respectively and watered for 14 days after treatment (DAT). This study observed the number of seeds that emerged at 2-day intervals for 14 days and the total water content of seedlings. The roots and shoots were weighed and dried at 80°C for 48 h [12] and then the total water content of the seedlings was calculated. Parameters were analyzed using analysis of variance and duncan's multiple range test (DMRT) at $P<0.05$. The heritability of both parameters was also calculated.

3 Results and discussion

Local maize varieties and PEG-6000 dosage significantly affected the number of seeds germinated from 2 to 14 DAT (Table 1) while their interaction was only significant at 2 DAT (Table 2). The number of seeds germinated by four local varieties, namely LSB1, 3, 5, and LDS2 were significantly different compared to other local and hybrid varieties. Other results showed that increasing the PEG doses to 500 g L-1 inhibited the number of seeds germinated by 32.27% compared to the control. The interaction of LDS1 with control (0 g L-1 PEG) showed the highest number of seeds germinated at 4.00 seedlings compared to other interactions at 2 DAT.

Table 1. The number of seeds germinated of local maize varieties and PEG doses from 2 to 14 days after treatment (DAT).

Treatments	Days after treatment (DAT)						
	2	4	6	8	10	12	14
Varieties							
H	0.00 c	6.33 abc	13.56 abc	17.06 b-e	20.39 a-d	22.28 a-d	26.44 bc
LB1	0.44 abc	5.00 a-d	12.89 a-d	15.11 c-g	17.33 c-f	18.61 def	21.50 cd
LB2	0.00 c	1.78 de	7.89 efg	10.22 gh	12.94 ef	14.17 f	17.22 d
LB3	0.44 abc	7.06 ab	15.22 ab	18.00 a-e	20.22 a-d	21.56 bcd	28.44 b
LSB1	0.00 c	5.33 a-d	13.61 abc	21.28 ab	23.72 ab	25.50 ab	37.67 a
LSB2	0.11 bc	0.89 e	7.39 fg	11.33 fgh	13.28 ef	15.67 ef	27.28 bc
LSB3	0.22 abc	6.39 abc	13.67 abc	19.56 abc	22.83 abc	24.50 abc	37.00 a
LSB4	0.00 c	2.17 de	10.22 c-f	13.17 efg	17.67 cde	19.44 c-f	23.44 bc
LSB5	0.00 c	4.44 b-e	11.06 b-f	22.89 a	25.00 a	27.61 a	40.17 a
LDS1	0.72 a	2.72 cde	5.78 g	7.33 h	11.83 f	14.39 f	26.00 bc
LDS2	0.00 c	8.61 a	13.83 abc	18.22 a-e	20.83 abc	22.00 a-d	37.06 a
LDS3	0.61 ab	4.50 b-e	13.06 a-d	15.61 c-f	18.72 bcd	20.33 b-e	26.28 bc
LDS4	0.00 c	1.94 de	9.00 d-g	11.83 fgh	13.17 ef	14.89 ef	23.56 bc
LDS5	0.00 c	2.89 cde	8.44 efg	10.17 gh	12.33 ef	14.44 f	28.56 b
LMN1	0.00 c	4.56 b-e	12.28 a-e	14.11 d-g	15.11 def	16.67 def	21.83 cd
LMN2	0.00 c	3.83 b-e	16.78 a	18.56 a-d	19.83 a-d	22.00 a-d	25.94 bc
LMN3	0.00 c	2.78 cde	14.83 ab	19.61 abc	22.89 abc	24.50 abc	28.39 b
PEG doses (g)							
0	0.88 a	11.27 a	18.92 a	23.18 a	26.00 a	27.45 a	35.14 a
100	0.02 b	5.98 b	14.59 b	20.10 b	23.75 a	25.31 a	32.63 a
200	0.00 b	1.84 c	10.76 c	13.76 c	16.35 b	18.53 b	27.04 b
300	0.00 b	2.06 c	8.76 c	12.65 c	15.00 b	17.18 bc	25.65 b
400	0.00 b	1.88 c	8.43 c	11.76 c	14.00 b	15.82 bc	24.02 b
500	0.00 b	2.10 c	8.94 c	11.75 c	13.65 b	15.20 c	23.80 b
CV (%)	4.66	9.29	16.78	14.56	13.60	12.59	9.63

Note: averages followed by different letters in the same column indicate significance by DMRT at $P<0.05$. H= hybrid maize; L= local maize.

The total water content of the seedlings in four local maize varieties, such as LSB4, LDS3, LMN2, and LMN3 were significantly different compared to other local and hybrid varieties (Figure 1A). Increasing the PEG doses to 500 g L-1 inhibited the total water content of the

seedlings by 11.45% compared to the control (Figure 1B). The PEG doses to the total water content of the seedlings had a negative linear relationship pattern with the equation ŷ= -1.5008D+74.576. Although the effect was insignificant, the interaction of LDS3 with 0 g l-1 PEG showed the highest total water content of the seedlings at 78.45% compared to other interactions.

Table 2. Interaction of local maize varieties with PEG doses on the number of seeds germinated and total water content of seedlings from Binjai City (LB), Serdang Bedagai (LSB), Deli Serdang (LDS), and Mandailing Natal (LMN) Districts.

Maize varieties	PEG doses (g L^{-1})	Days after treatment (DAT)							Total water content
		2	4	6	8	10	12	14	
H	0	0.00 c	19.67	26.33	33.00	37.67	38.67	39.67	75.02
	100	0.00 c	4.00	13.00	17.67	22.67	25.33	30.33	74.27
	200	0.00 c	3.33	18.33	21.67	25.67	27.00	30.00	73.36
	300	0.00 c	2.33	8.33	10.33	12.67	15.67	19.33	69.30
	400	0.00 c	4.33	7.33	9.33	11.67	13.33	18.00	66.60
	500	0.00 c	4.33	8.00	10.33	12.00	13.67	21.33	64.33
LB1	0	2.67 b	15.67	17.33	19.67	21.67	23.33	26.33	62.24
	100	0.00 c	9.33	18.33	20.33	22.67	24.00	25.33	55.57
	200	0.00 c	1.33	4.67	5.33	6.33	7.33	17.00	54.05
	300	0.00 c	2.00	10.00	12.33	14.00	15.67	16.00	47.97
	400	0.00 c	1.00	13.67	16.33	18.67	19.33	21.67	56.02
	500	0.00 c	0.67	13.33	16.67	20.67	22.00	22.67	52.60
LB2	0	0.00 c	8.33	15.67	20.00	24.33	25.00	26.00	73.41
	100	0.00 c	0.67	11.67	16.00	20.00	20.67	22.67	60.30
	200	0.00 c	0.67	4.33	5.67	7.33	8.33	10.67	53.78
	300	0.00 c	0.67	4.67	6.67	10.00	11.33	12.33	71.55
	400	0.00 c	0.00	3.33	4.00	5.33	7.33	14.67	66.18
	500	0.00 c	0.33	7.67	9.00	10.67	12.33	17.00	71.34
LB3	0	2.67 b	21.67	26.00	28.00	30.00	30.67	34.00	66.82
	100	0.00 c	15.00	18.67	26.33	31.33	33.00	36.67	63.75
	200	0.00 c	2.33	15.00	17.67	21.00	22.00	27.00	64.01
	300	0.00 c	1.33	18.00	18.67	20.00	22.00	24.67	56.35
	400	0.00 c	0.67	9.33	11.00	11.67	12.67	19.00	60.45
	500	0.00 c	1.33	4.33	6.33	7.33	9.00	29.33	55.78

Continued Table 2. Interaction of local maize varieties with PEG doses on the number of seeds germinated and total water content of seedlings from Binjai City (LB), Serdang Bedagai (LSB), Deli Serdang (LDS), and Mandailing Natal (LMN) Districts.

Maize varieties	PEG doses (g L^{-1})	Days after treatment (DAT)							Total water content
		2	4	6	8	10	12	14	
LSB1	0	0.00 c	19.00	22.33	33.33	35.00	35.67	43.33	75.41
	100	0.00 c	5.67	19.33	25.33	31.00	32.33	38.67	72.28
	200	0.00 c	2.00	14.67	18.00	20.33	21.00	40.00	71.10
	300	0.00 c	0.00	8.00	14.00	16.00	18.67	35.33	62.56
	400	0.00 c	1.67	8.33	18.67	20.67	24.00	34.33	62.13
	500	0.00 c	3.67	9.00	18.33	19.33	21.33	34.33	56.82
LSB2	0	0.67 c	1.00	8.67	12.00	15.00	17.00	27.33	71.73
	100	0.00 c	2.33	10.33	14.67	15.67	17.67	40.67	69.88
	200	0.00 c	0.33	7.67	13.00	14.00	17.33	24.67	69.06
	300	0.00 c	0.67	7.33	11.33	14.33	17.00	30.33	67.39
	400	0.00 c	0.67	6.67	12.33	13.67	16.33	26.00	66.40
	500	0.00 c	0.33	3.67	4.67	7.00	8.67	14.67	64.47
LSB3	0	1.33 c	18.33	21.33	29.33	30.33	31.67	44.67	75.57
	100	0.00 c	12.33	19.33	30.00	33.33	34.67	44.33	73.97
	200	0.00 c	1.00	14.00	16.00	20.67	23.33	35.33	72.52
	300	0.00 c	1.67	5.00	14.33	19.33	21.67	38.67	75.15
	400	0.00 c	4.00	11.00	12.33	16.00	17.33	36.00	72.60
	500	0.00 c	1.00	11.33	15.33	17.33	18.33	23.00	65.62
LSB4	0	0.00 c	11.33	19.67	24.67	32.00	33.33	35.67	76.12
	100	0.00 c	0.67	11.67	14.33	26.33	27.00	29.33	75.36
	200	0.00 c	0.00	11.33	14.33	15.00	17.33	22.00	74.57
	300	0.00 c	0.00	6.00	9.67	12.33	15.00	21.00	75.40
	400	0.00 c	0.67	5.67	7.33	10.00	12.33	18.33	73.83
	500	0.00 c	0.33	7.00	8.67	10.33	11.67	14.33	71.33
LSB5	0	0.00 c	10.67	21.33	29.67	31.33	32.33	49.00	74.49
	100	0.00 c	10.00	16.33	33.00	37.33	40.00	44.33	70.14
	200	0.00 c	2.00	7.67	16.00	17.00	22.67	41.67	69.37
	300	0.00 c	1.00	6.33	23.00	23.67	25.67	40.67	68.95
	400	0.00 c	2.67	8.00	19.67	22.33	24.33	33.33	68.14
	500	0.00 c	0.33	6.67	16.00	18.33	20.67	32.00	66.49

Continued Table 2. Interaction of local maize varieties with PEG doses on the number of seeds germinated and total water content of seedlings from Binjai City (LB), Serdang Bedagai (LSB), Deli Serdang (LDS), and Mandailing Natal (LMN) Districts.

Maize varieties	PEG doses (g L^{-1})	Days after treatment (DAT)							Total water content
		2	4	6	8	10	12	14	
LDS1	0	4.00 a	6.00	11.67	13.67	23.33	27.00	33.33	75.64
	100	0.33 c	0.33	3.00	4.33	5.67	7.00	27.00	74.18
	200	0.00 c	1.00	3.00	5.33	10.67	13.67	23.33	73.27
	300	0.00 c	2.33	4.33	6.67	8.67	10.67	20.67	72.96
	400	0.00 c	1.33	6.33	6.67	8.33	12.67	21.00	71.48
	500	0.00 c	5.33	6.33	7.33	14.33	15.33	30.67	68.50
LDS2	0	0.00 c	9.33	15.33	18.67	21.00	22.00	42.00	77.29
	100	0.00 c	14.33	20.00	25.00	30.67	32.00	38.00	73.20
	200	0.00 c	1.00	5.00	8.33	11.00	12.00	32.67	69.34
	300	0.00 c	9.67	16.67	21.67	24.00	25.67	35.00	67.13
	400	0.00 c	6.00	11.00	17.33	18.67	19.33	35.67	64.61
	500	0.00 c	11.33	15.00	18.33	19.67	21.00	39.00	61.00
LDS3	0	3.67 ab	11.33	18.67	22.33	24.33	25.67	33.33	78.45
	100	0.00 c	5.67	17.00	19.67	23.33	24.33	29.00	74.39
	200	0.00 c	2.67	8.00	10.00	13.33	15.67	27.67	74.41
	300	0.00 c	3.67	13.33	15.00	17.67	20.67	25.33	73.13
	400	0.00 c	3.00	12.00	15.67	21.00	21.67	23.67	72.91
	500	0.00 c	0.67	9.33	11.00	12.67	14.00	18.67	71.04
LDS4	0	0.00 c	5.33	11.00	15.00	16.00	17.33	21.67	73.35
	100	0.00 c	1.33	11.00	15.67	17.00	18.33	25.33	73.06
	200	0.00 c	2.33	17.00	22.67	24.67	27.00	30.00	71.39
	300	0.00 c	0.00	5.00	6.00	6.67	8.67	28.00	70.56
	400	0.00 c	2.67	5.67	6.33	8.33	10.33	20.33	67.58
	500	0.00 c	0.00	4.33	5.33	6.33	7.67	16.00	65.93
LDS5	0	0.00 c	5.33	11.67	13.33	15.00	17.33	35.67	72.91
	100	0.00 c	5.67	10.00	11.33	14.00	16.67	31.33	70.97
	200	0.00 c	3.67	13.00	15.33	18.33	20.67	25.33	68.32
	300	0.00 c	0.67	4.33	6.67	9.67	11.33	23.33	67.01
	400	0.00 c	1.00	6.00	8.00	10.00	12.33	28.00	66.95
	500	0.00 c	1.00	5.67	6.33	7.00	8.33	27.67	64.91

Continued Table 2. Interaction of local maize varieties with PEG doses on the number of seeds germinated and total water content of seedlings from Binjai City (LB), Serdang Bedagai (LSB), Deli Serdang (LDS), and Mandailing Natal (LMN) Districts.

Maize varieties	PEG doses (g L^{-1})	Days after treatment (DAT)							Total water content
		2	4	6	8	10	12	14	
LMN1	0	0.00 c	12.33	24.67	27.33	28.67	30.00	36.33	74.97
	100	0.00 c	5.67	16.67	18.33	20.33	22.00	28.00	73.17
	200	0.00 c	3.33	11.67	12.67	14.67	17.33	22.00	73.28
	300	0.00 c	4.00	8.33	10.33	10.67	12.33	16.67	73.34
	400	0.00 c	1.67	6.00	7.67	8.00	8.67	13.00	72.95
	500	0.00 c	0.33	6.33	8.33	8.33	9.67	15.00	69.05
LMN2	0	0.00 c	8.33	25.33	27.67	28.33	30.00	34.00	75.36
	100	0.00 c	4.00	19.67	21.67	23.33	25.00	28.67	76.04
	200	0.00 c	2.33	13.67	15.33	15.67	17.67	21.67	74.48
	300	0.00 c	3.67	13.67	14.67	16.00	19.33	24.33	73.71
	400	0.00 c	0.33	9.33	11.00	14.00	16.00	21.00	72.22
	500	0.00 c	4.33	19.00	21.00	21.67	24.00	26.00	71.39
LMN3	0	0.00 c	8.00	24.67	26.33	28.00	29.67	35.00	76.17
	100	0.00 c	4.67	12.00	28.00	29.00	30.33	35.00	75.81
	200	0.00 c	2.00	14.00	16.67	22.33	24.67	28.67	73.88
	300	0.00 c	1.33	9.67	13.67	19.33	20.67	24.33	72.61
	400	0.00 c	0.33	13.67	16.33	19.67	21.00	24.33	72.03
	500	0.00 c	0.33	15.00	16.67	19.00	20.67	23.00	70.74
Heritability (h2)								77.36 % (H)	66.52 % (H)

Note: averages followed by different letters in the same column indicate significance by DMRT at $P<0.05$. Heritability classification according to [13] includes low <20%; moderate= 20-50%; and high >50%.

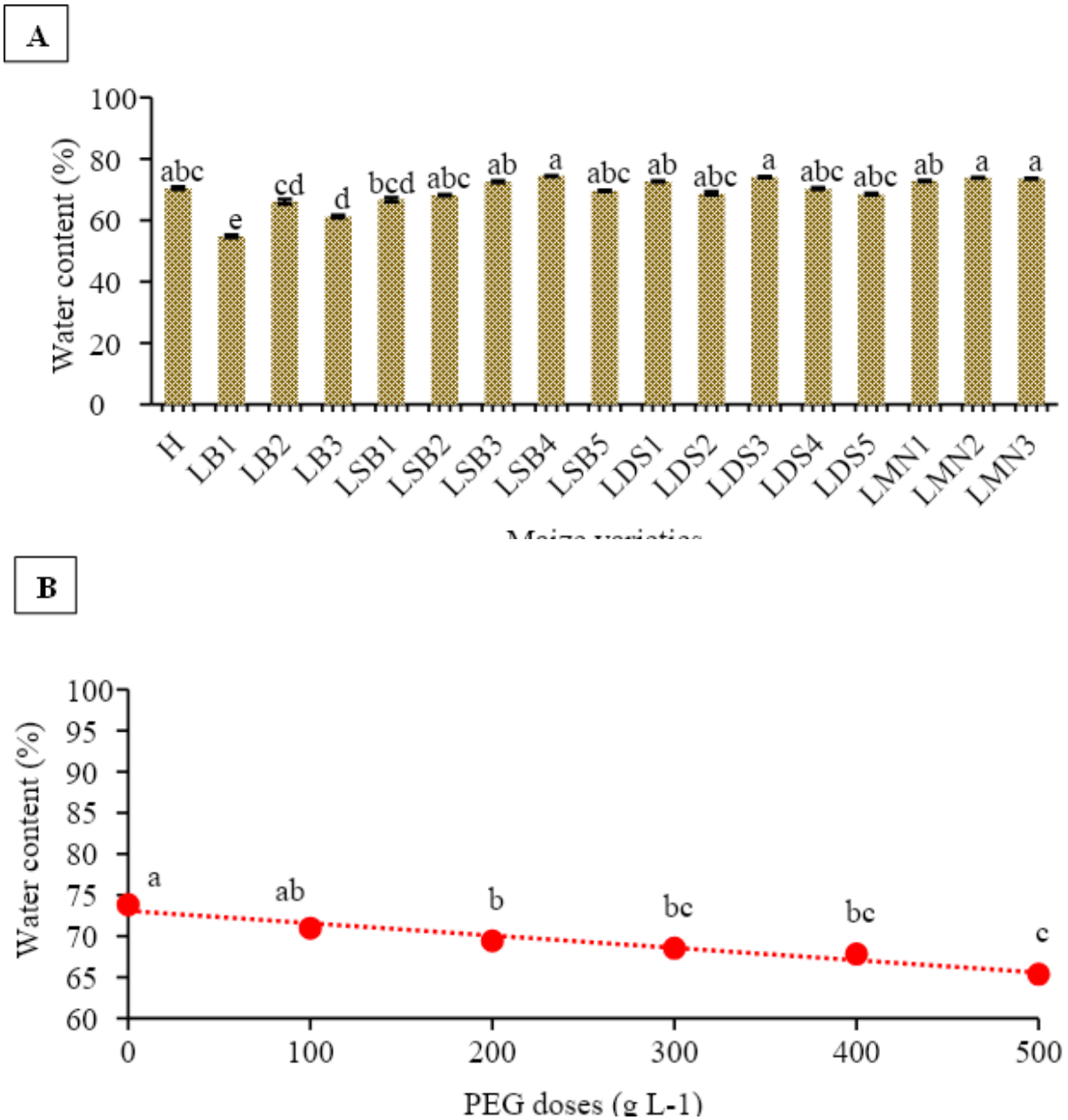

Fig. 1. The total water content of the seedlings from local maize varieties (A) and PEG doses (B). CV= 11.91%.

The number of seeds germinated seeds and the total water content of the seedlings were significantly influenced by the local maize varieties. The highest number of seeds germinated and total water content of the seedlings were found in LSB5 and LSB4 at 40.17 seedlings and 74.43%, respectively. It indicates that both local maize characteristics are dominantly influenced by genetic factors marked by high heritability at 77.36 and 66.52%, respectively (Table 2). Both characteristics are likely to be inherited from the parents to the first generation (F1), resulting in the LSB4 and LSB5 (Serdang Bedagai) of local varieties showing slightly changes in their characteristics from their parents although under drought stress with a PEG. These findings are supported by [14] that the heritability value of maize characteristics in the first generation (F1) applied to drought stress was similar to its parents (F0) and the most successful selection was found in the second (F2) to the third (F3) generations. [15] found that the characteristics of maize germination under drought stress were classified as high ranging from 62.09 to 89.56%. [16] added that the heritability of

germination, fresh and dry weight of maize plants was classified as high in 10% PEG treatment.

The number of seeds germinated and total water content of the seedlings were significantly affected by the PEG doses. The increasing dose of PEG up to 500 g L^{-1} inhibited the number of seeds germinated and total water content of the seedlings by 32.27 and 11.45% compared to the control. The inhibition of both characteristics was due to the interruption of physio-biochemical and DNA processes from the PEG application. These findings are supported by [17] that drought stress induced the production of reactive oxygen species (ROS) and fragment unsaturated fatty acids that cause structural degradation of seeds and inhibit germination. [18] reported that an increase in ROS caused oxidative damage to lipids, proteins, and DNA. [19] added that there was a decrease in water content, germination, fresh and dry weight along with an increase in PEG concentration to 20%. [20] found that a decrease in chlorophyll, carotenoids, and relative water content, but increased the ascorbate peroxidase, catalase, peroxidase, and superoxide dismutase enzymes due to the 15% PEG application in sensitive and drought-tolerant plants. [21] explained that leaf water content, cell membrane stability, root: shoot ratio, and seedling vigor index play an important role as indicators of drought-tolerant plants.

The number of seeds germinated was significantly affected by the interaction of local varieties with PEG doses at 2 DAT, but it was insignificant from 4 to 14 DAT and the total water content. It is due to the heritability value of the number of germinated seeds and total water content in local maize in the first generation (F1) which are classified as high or dominantly influenced by genetic factors from the parents. The first generation was suboptimal for obtaining changes in the characteristics of maize seedlings in the preliminary selection of drought stress with PEG. These findings are supported by [14] that the optimal selection in drought-stressed maize was found between the second and third generations. [22, 23] also added that genetic improvement can be achieved in the initial cycle and subsequent repeated cycles.

Among the local varieties tested, LSB4 and LSB5 from Serdang Bedagai District performed more superior to drought stress at early selection. Both local varieties should be re-examined for drought tolerance by field capacity testing to validate their tolerance mechanism until the subsequent generations. However, the preliminary information is highly important for the development of local maize varieties for scientists, practitioners, and other institutions.

4 Conclusions

Local maize varieties and PEG doses significantly affected the number of seeds germinated and total water content of the seedlings, but the interaction was insignificant. LSB5 and LSB4 local maize from Serdang Bedagai had the highest number of seeds germinated and total water content of the seedlings at 40.17 seedlings and 74.43%, respectively. The number of seeds germinated and total water content of local maize seedlings were inhibited along with the increase of PEG doses up to 500 g L^{-1} by 32.27 and 11.45%.

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