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Synthesis and Evaluation of Maize (*Zea mays* L.) Accessions under Naturally Flooded Tidal-swamp Area

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ABSTRACT

Background: Synthesis and introduction of adaptive open-pollinated-maize accessions may help farmers at tidal-swamp to increase income, since farmers can produce the seeds directly from their plantation.

Methods: This research utilized fields and farmers of such area located at South Sumatera, Indonesia. Evaluated plants consisted of Unsri-J1 to J8-accessions, generated from recurrent-selections of double-crossing populations between Indonesian varieties and introduced-accessions of high-quality protein maize (HQPSSS) from Purdue University, and acid-soil tolerant accession maize (SA3) from CIMMYT. Evaluation was designed as randomized complete block. Measurements were taken on five observation-plots consisted of 25 plants/plot. Statistical analysis was performed by using Analysis of Variance, followed by Fisher's protected-LSD-test.

Result: Research indicated that most accessions showed good performance. The plant-height ranged 200 to 228 cm and anthesis-period at 44 to 46 days after-planting. The half-sib seeds production ranged from 2.20 to 2.93 t/ha and the real-yield, at farmer level, ranged 5.5 to 7.7 t/ha and the potential-yield reached 7.6 to 9.6 t/ha with protein-content ranged from 8.57 to 9.48%. This research suggested that accessions of Unsri-J6, followed by Unsri-J7, J2, J5 and J1 were promising for further development.

Key words: Acid-soil, Evaluation, Maize, Open-pollinated, Protein, Tidal-swamp.

INTRODUCTION

Maize or corn (*Zea mays* L.), in general, was considered as a dry-land crop. Due to land competition and limitation, maize begin to be cultivated at tidal-swamp type areas. Sulistiyani *et al*. (2014) stated that farmers in the tidal-swamp area of Indonesia only cultivated maize once a year, usually in dry-season. Farmers did not cultivate in wet-rainy season, to avoid flooding, lethal-effect of acidity, and element-toxicity. Notohadiprawiro (1986) said that tidal-swamp area was interrupted by movement of water-level that will increase the risk of element-toxicity such as Al^{+}, Fe^{+} and Mn^{+}. In the extreme condition, the plants will be sub-emerged and encountered oxygen-deficiency. Imanuddin *et al*. (2010), revealed that in this situations, soil condition was to be very critical, because of high content of Fe^{+}, with Al-exchange could reach >5 cmol kg^{-1}.

Effort to developed crop varieties adapted to tidal-swamp area in Indonesia, has been done by researchers for several crops. Wirosoedarmo *et al.* (2011), stated that a long with a proper application of technology, a tidal-swamp area was a potential to cultivate maize and soybean (Kuswantoro *et al.*, 2017). Subandi *et al.* (2006), Pabbage *et al*. (2008), explained proper technologies to cultivate maize in tidal-swamp area, including utilization of varieties that tolerant to sub-emerged condition and soil-acidity. Immanudin *et al*. (2010), furthermore, recommended to incorporate water management to support maize cultivation in naturally-flooded tidal-swamp areas. While Visalakshi and Sireesha (2015), stated to consider soil-tillage methods to maximize maize production.

Approach to develop maize varieties adapted to tidal-swamp area could be done by selecting accessions tolerant to acid soil, as the main problem in this area. By the year 1980's Indonesian's maize researchers have turned their attention to tidal-swamp area by developing an open-pollinated variety that tolerant to acid-soil, namely variety of *"Antasena"* (Subandi *et al*., 2006). Several seed-companies also turned their attention to produce maize seed. For maximum profit, however, they prefer to produce hybrid, instead of open-pollinated varieties. Indonesian Center for Agricultural Development Agency, that was well known as "Puslitbangtan Kementrian Pertanian RI" (2017), released open-pollinated varieties of *"Sukmaraga"* and*"Pallaka"*. These two maize-varieties were claimed tolerant to soil-acidity, with real and potential-yield about 6.0 t/ha and 8.5 t/ha dry seeds, respectively.

In response to agriculture program of Indonesian government (GOI), research by Halimi *et al*. (2011) developed several open-pollinated maize accessions tolerant

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to soil, with high-quality protein content. The research program, so far, has resulted eight maize accessions namely Unsri-J1 to J8 (Halimi, 2017). This research, therefore, was carried out to produce half-sib seeds and field evaluation of these accessions at naturally-flooded tidal-swamp area. This research was also intended to introduced our open-pollinated maize accessions, so the farmers were able to directly produce the seeds for next season from their plantation.

MATERIALS AND METHODS

Genetic sources and production half-sib seeds.

Genetic source of this research derived from "Maize Breeding Program at Faculty of Agriculture Universitas Sriwijaya" (Halimi, 2017). This breeding program utilized "Top-cross"-populations of two Indonesian varieties of "*Arjuna*" and "*Antasena*" by introduced accessions of SA-3 and HQPSSS, resulting GS-5, GS-10, Toray-1 and Toray-2 populations (Fig 1). The SA-3 was a soil-acid tolerant-maize developed by Granados, *et al.* (1995) of CIMMYT, Mexico and the HQPSSS was a high-quality protein maize developed by Zehr and Hammaker *et al*. (1995), of Purdue University USA. The SA-3 and HQPSSS seeds were introduced to Indonesia based on letter of authorization from the Ministry of Agriculture Republic of Indonesia No. 220.226, 4 April 1996 (Halimi and Gofar 2000). Furthermore, crossing Toray and GS populations (double-cross) resulted maize populations having characters of tolerant to acid soil and high quality-protein content. As showed in (Fig 1), so far, there were eight maize-accessions to be used as genetic materials in this research.

The breeding program mainly involved methods of screenings, crossings, and selections. The screening for tolerant to acid-soil was done by using "Nutrient culture" method developed by Rhue and Grogan (1977) and screening for high-quality protein content utilized an "Integral system" method developed Villegas (1975). Controlled crossing methods of "poly-crossing" to produce full-sib seeds and natural crossing to produce half-seed family were utilized in each step of selection. The recurrent genotypic and phenotypic selection (RGS and RPS) methods along with "ear to row" arrangement planting method, as described by Hallauer (1992), were deployed in several steps of growing, evaluating, and selecting superior plants. Series researches reported by Halimi and Gofar (2000), Halimi and Rahayu (2001), resulted in superior maize populations of GS and Toray accessions. Furthermore, series researches reported by Halimi *et al.* (2011), Simanjuntak (2015) and Sinulingga (2015) resulted in eight open-pollinated maize populations, derived from double crossing of GS by Toray accessions. Later on, these eight maize accessions to be used in the research, were called as open-pollinated Maize accessions of Unsri-J1 to Unsri-J8 (Table 1).

For the purpose of this research, stock seeds of Unsri-J1 to Unsri-J8 accessions were planted, in-cooperation with a local farmer at tidal low-land area (soil pH 4.0-4.6) of Tanjung Lago, district Banyuasin, South Sumatera (2°36′02.6″S and 105°05′05.9″E) on June to August 2018. Each accession was planted at 20 × 10 m-plot, with planting distance of 70 cm × 20 cm. Standard practices for fertilization of 300 kg/ha Urea, 100 kg/ha SP36 and 100 kg/ha KCl. Manual weeding, and negative selection to eliminate undesirable plants, were applied by the farmers. No-isolation neither artificial-crossing were applied, and therefore, resulted seeds were considered as a half-sib seed family.

Field evaluation, protein content and data analysis

Field evaluation was carried out at naturally flooded tidal-swamp in-cooperation with local farmers of Air Sugihan, Distric Banyuasin, South Sumatra, Indonesia (2°35′57.6″S and 105°05′05.05″E) on November 2018 to January 2019. The area to grow the plants was about 0.5 ha/accession. This area were tidal low-land of type C and D, in which the land was naturally flooded during wet-rainy season, about 30 to 50 cm deep (Rahmadi *et al*., 2010). Laboratory test using composite samples, indicated acidity level (pH) of 3.59 to 4.72.

For the purpose of this reseacrh, land preparation was done by using hand-tractor. Seeds were directly planted manually, in 70 cm × 20 cm distance. Fertilizers were manually applied, consisted of 300 kg/ha Urea, 100 kg/ha SP36 and 100 kg/ha KCl. No-pesticide application and weedings were done two times at first and second-month after planting. Because of high rain-fall (>200 mm/day) occured during period of research, the area was naturally flooded 3 times, at about 1, 2 and 3 months after planting, for about 2-4 days each (Fig 2). Local weather station reported the rain-fall of about 250-310 mm/day. Laboratory analysis on the composite samples indicated pH of 3.90, with 0.071 mg/l Fe, 0.0031 mg/l Mn and Al-exchange reached 5.30 cmol/kg.

Measurement on the plants were taken on 5 observation sub-plots per accession, located at center and at each corner of the plot. Each observation sub-plot consisted of 25 sample-plants (total 125 plants/accession). Visual observation on periode of >70% anthesis and real-yield (yield at farmer level) were recorded based on entire field in each accession, while other measurements and potential-yield were calculated based on each respected observation sub-plot. Protein content was measured using a random sample seed from eah accession, about 250 g each. Protein nalysis was carried out by an independent laboratory of "Balai Besar Industri Agro", Bogor, Indonesia by using standard kjedall method of SNI.01-2891-1992. Statistical analysis were aproached by using randomized block design (Milliken and Johnson, 1992). Caculation of analysis of variances (Anova) and Fisher's protected LSD-test were carried out by using computer application of Statistical Analysis System (SAS-Institute, 1988).

RESULTS AND DISCUSSION

Production of half-sib seeds

As described above, after generations of selection, our breeding program resulted in eight open-pollinated maize accessions (Table 2). The purpose of developing such type

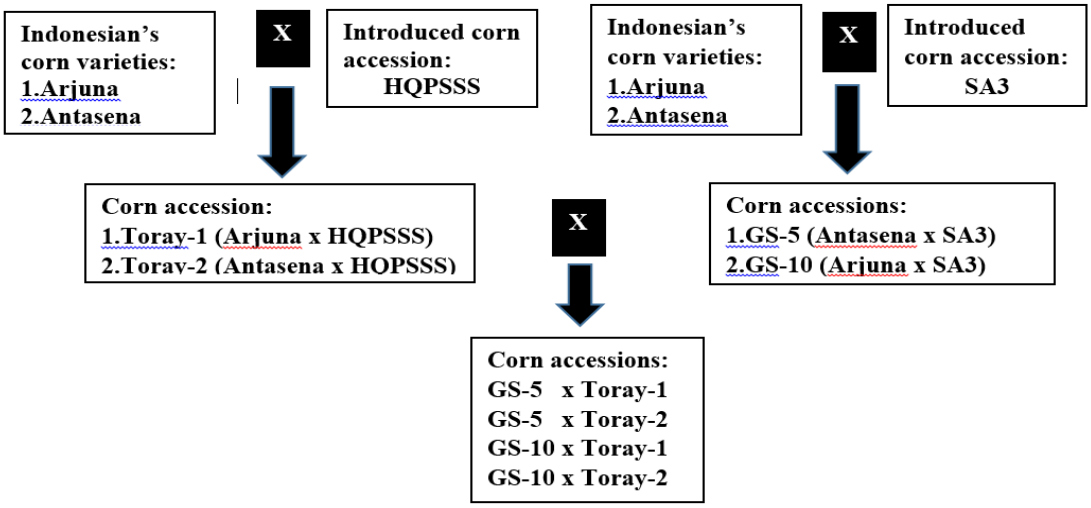


Fig 1: Crossing-scheme between Indonesian-maize varieties by introduced-maize accession of HQPSSS and SA3 to develop materials for this research (Halimi, 2017).

Table 1: Amount of half-sib seeds resulted from 20 × 10 m-plot, 70 × 20 cm-planting-distance and their potential-seed-production of each maize-accessions cultivated during dry season at tidal swamp-area, South Sumatera, Indonesia.

Accession	Parental origin	Amount of seeds (kg/plot)	Potential-seed-production (t/ha)
Unsri-J1	GS-5 × Toray-1	35	2.50
Unsri-J2	GS-5 × Toray-2	38	2.71
Unsri-J3	GS-10 × Toray-1	31	2.21
Unsri-J4	GS-10 × Toray-2	30	2.20
Unsri-J5	GS-5, (Antasena × SA3)	37	2.64
Unsri-J6	GS-10, (Arjuna × SA3)	40	2.86
Unsri-J7	Toray-2, (Arjuna × HQPSSS)	41	2.93
Unsri-J8	Toray-1, (Antasena × HQPSSS)	33	2.36

accessions is to help farmers at tidal-swamp area to increase income, since the farmers can produce the seeds for next planting-season directly from their recent-plantation. As stated by Hallauer (1992), that a long with the application of simple mass-selection, seeds for next plantation of open-pollinated varieties can be produced by saving seeds from current plantation. This method of seed production can be repeated for generations of planting.

The seeds to be used in this research were produced in cooperation with the local farmers. The plants were planted in months June to August, which were considered as dry season and therefore, no-flood recorded during this season. The amount of seeds resulted from this research varied from 30 to 41 kg or about 2.20 to 2.93 t/ha dry seeds (Table 1). Standard practices in seed production applied by farmers, including negative-selection by removing inferior plants form the field, and only used seeds from the middle-part of cob. As compared to real and potential yield, these practices, ultimately reduce the amount of seeds resulted from the field.

Field evaluations

Field evaluation was carried out in the months of November to January, which were considered as wet-rainy season. During period of the research, there were very high rain-fall (>200 mm/day) occured three times, at about 1, 2 and 3.

Table 2: The F-values and coefficient of variation (CV) resulted from the analysis of variances on the variables observed on accessions of Unsri-J1 to J8 cultivated by the farmers at naturally flooded tidal-swamp area, South Sumatera Indonesia.

Variable observed	F-value	CV (%)
Plant-height (cm)	1.81^{ns}	8.62
Ear-position (cm)	3.29*	15,00
Cob-length (cm)	5.69*	11.47
Cob-diameter (cm)	4.63*	6.05
Cob-weight (g)	3.38*	19.29
Number seeds/cob	2.57*	16.51
Weight of dry seeds/cob (g)	3.62*	20.41

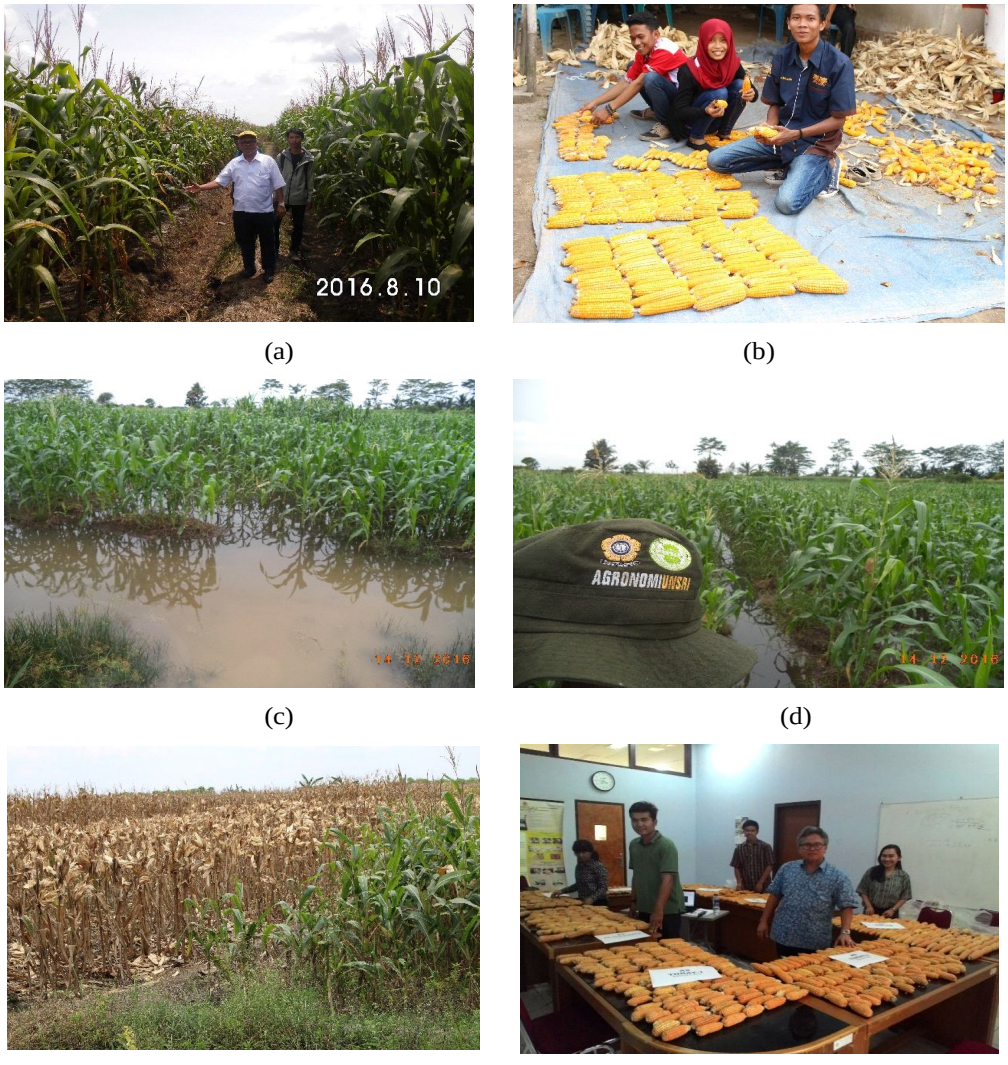
Note: *= Significant and ns= Not-significant at α=0.05.

months after planting. The rain caused the area was flooded 25 to 50 cm deep, for about 2-4 days. The plants, however, were still able to survive, to grow as usual, and no-significant physical damage was observed (Fig 2).

Results of analysis of variance (Table 2) indicated significant differences among accessions, except for plant-height that relatively similar (about 200 to 228 cm). Anthesis period was also about similar at 94 to 106 days after planting. The ear position was significant among accessions (71 to 94 cm). The ear positions, however, were <50% of the plant-height (220 to 228 cm). The ear position that was < 50% of the plant-height, was an important character to reduce lodging sensitivity.

Measurement and data analysis on the growth variables, indicated that accession of Unsri-J8, showed relatively more vigourous than other accessions. Furthermore, growth performace of these eight accessions were comparable to variety of "*Sukmaraga*" (an acid-soil tolerant Maize variety released by GOI) with plant-height of 180 to 220 cm and ear position of 90 to100 cm (Puslibangtan Kementrian Pertanian RI, 2017).

Statistical analysis on yield-variables indicated significantly different on length, diameter and weight of cob, (Table 2 and Fig 3). Con-length ranged from 15 to 18 cm, with cob-diameter about 4 cm and cob-weight ranged from 144 to 183 g. Measurements on corn-cob is important to predict potential yield of maize, as larger cob indicated higher yield potential. Based on yield-data, the most potential accession was Unsri-J6, followed by J2, J7, J5, J3, J1 and J4, respectively. A statistical analysis on number and weight of dry-seeds per cob indicated significantly different (Table 2 and Fig 3). The weight and number of the seeds ranged 107 to 135 g/cob, respectively. In relation to these data, Unsri-J6 accession was considered



(a) (b) (c) (d) (e) (f)

Fig 2: Maize plantations (a,c) handling seeds (b, f) and flooding condition (c,d) that naturally-occurred during period of field evaluation of Unsri-J1 to J-8 accessions at tidal-swamp area, South Sumatera, Indonesia.

as the most potential with dry-seed-weight of 135 g/cob or about 9.67 t/ha (Table 3 and Fig 3).

Furthermore (Table 3) showed the potential-yield of accessions of Unsri-J1 to J8 ranged from 7.79 to 9.67 t/ha dry-seeds, while the real-yield at farmer level ranged from 5.53 to 7.75 t/ha. Comparing these yield-data to national - maize variety of "*Sukmaraga"* with potential-yield and real-yield at farmer level of 8.50 and 6.0 t/ha dry-seeds, respectively (Puslibangtan Kementrian-Pertanian RI, 2017), this research reavealed five open-pollinated maize

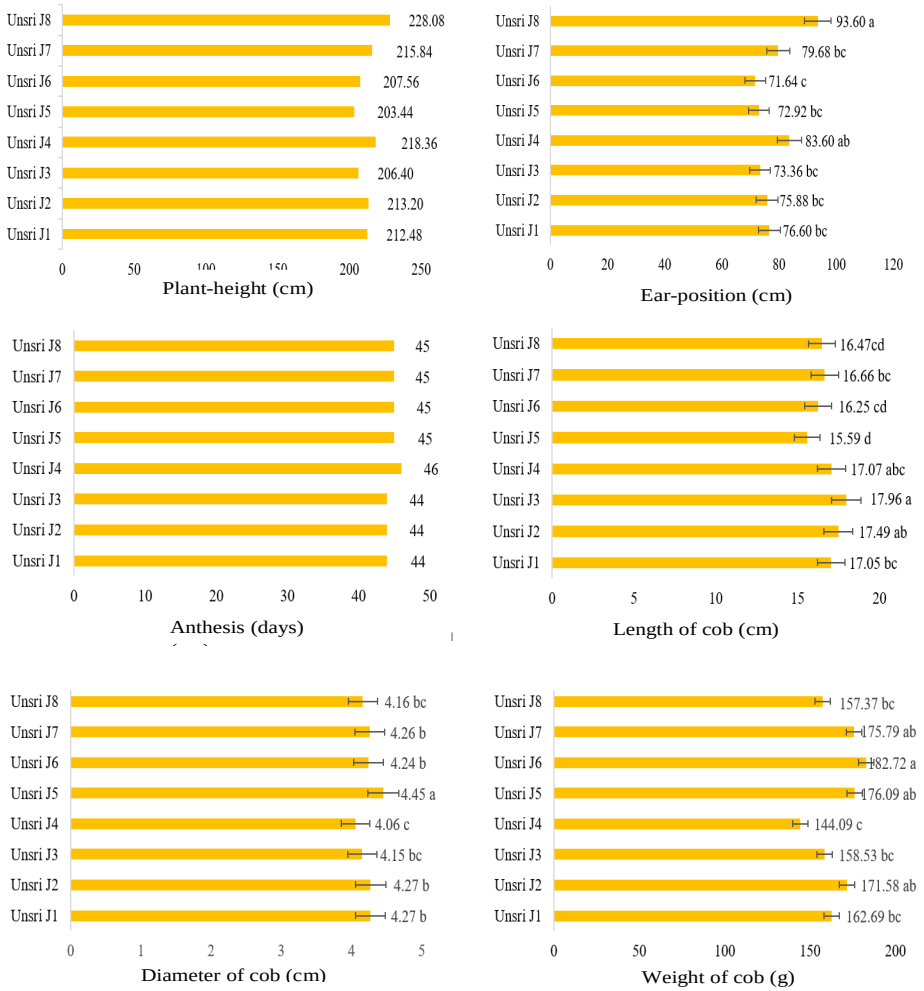


Fig 3: Plant-height; ear-position; anthesis-period; length, diameter and weight of cob, of Unsri-J1 to J8 accessions, cultivated at naturally-flooded tidal-swamp area of Sumatera, Indonesia. The number followed by the same letter indicated not-significantly-different according to LSD-test at α=0.05.

Table 3: Average of potential-yield and real-yield at farmer level and protein content of accessions of Unsri-J1 to J8 cultivated at naturally-flooded tidal-swamp area of South Sumatera, Indonesia.

Accession	Potential-yield* (t/ha)	Real-yield at farmer level (t/ha)	Protein content (%)
Unsri-J1	8.76±0.21¶	6.54¶	8.96
Unsri-J2	9.41±0.36¶	7.02¶	8.99
Unsri-J3	8.09±0.31	5.85	8.79
Unsri-J4	7.79±0.34	5.53	8.90
Unsri-J5	9.38±0.33¶	6.90¶	8.57
Unsri-J6	9.67±0.35¶	7.75¶	9.16
Unsri-J7	9.46±0.23¶	7.22¶	9.30
Unsri-J8	8.22±0.24	6.36¶	9.48

Note:*= Calculated based on 70 x 20cm-planting-distance ¶= The values were higher than yield of national-maize variety of "Sukmaraga".

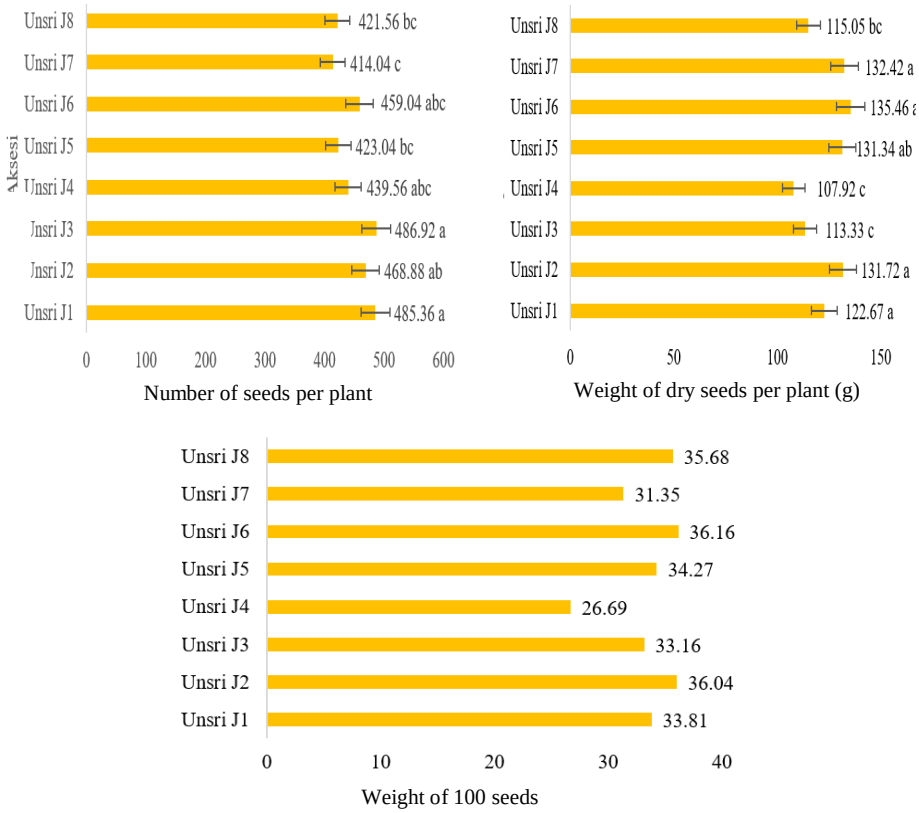


Fig 4: Number and weight of dry-seeds/plant and weight of 100 dry-seed of Unsri-J1 to J8 accessions, cultivated at naturally-flooded tidal-swamp area of South Sumatera, Indonesia. The numbers followed by the same letters indicated not-significantly different according to LSD-test at α= 0.05.

accessions with potential-yield and real-yield at farmer level were 6% to 29% higher than national variety of *Sukmaraga*. Those five accessions were Unsri-J6, J7, J2, J5 and J1 with potential-yield of 9.67, 9.46, 9.41, 9.38, 8.876 and real-yield at farmer level of 7.75, 7.22, 7.02, 6.90, and 6.54 t/ha dry-seeds, respectively. Furthermore, analysis protein conducted by an independent laboratory showed promising protein content of 8.57% to 9.48% (Table 3).

CONCLUSION

This research program developed eight Maize accessions, namely Unsri-J1, J2, J3, J4, J5, J6, J7 and J8. These accessions were open-pollinated-type v cultivars, performed well at naturally-flooded tidal-swam area with plant-height ranged from 200 to 228 cm and anthesis at 44 to 46 days after-planting. The real-production at farmer level ranged from 5.5 to 7.7 t/ha, while the potential-yield reached 7.6 to 9.6 t/ha dry seed with protein content ranged from 8.57 to 9.48%. Production of their half-sib seed during dry season ranged from 2.20 to 2.93 t/ha. This research suggested that Unsri-J6, J7, J2, J5 and J1 were promising accessions to be new maize cultivars.

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