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Drought-adapted maize line based on morphophysiological selection index

RUSNADI PADJUNG[1,♥], MUH FARID[1,♥♥], YUNUS MUSA[1], MUHAMMAD FUAD ANSHORI[1], AMIN NUR[2], ANDI MASNENONG[3]

[1]Department of Agronomy, Faculty of Agriculture, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km 10, Makassar 90245, South Sulawesi, Indonesia. Tel. +62 81355041712, ♥email: rusnadi2015@gmail.com, ♥♥email: farid_deni@yahoo.co.id
[2]Assessment Institute for Agriculture Technology of Gorontalo. Jl. Mohamad Van Gobel No. 270, Iloheluma, Bone Bolango 96583, Gorontalo, Indonesia
[3]Program of Agrotechnology, Faculty of Agricultural, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km 10, Makassar 90245, South Sulawesi, Indonesia

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Abstract. *Padjung R, Farid M, Musa Y, Anshori MF, Nur A, Masnenong A. 2021. Drought-adapted maize line based on morphophysiological selection index. Biodiversitas 22: 4028-4035.* Synthetic line formation is an effort to increase maize productivity in drought-stressed areas. This process requires systematic selection in determining adaptability levels involving important secondary characters formulated in the selection index. Furthermore, the principal component index had been widely reported, both in normal and stressed conditions. The selection index development on morpho-physiological characters based on multivariate analysis was expected to increase drought stress tolerance and maize lines selection precision. Therefore, the purpose of this research was to form a selection index based on morpho-physiological characters and selecting synthetic lines adaptive under drought stress. This research was designed using a split-plot with 3 replications, where the main plot consisted of normal and stressed irrigation, while the subplot was genotype consisting of 6 lines and 3 check varieties namely Bisma, Lamuru, and Sukamarga. Observations were performed on 18 morphological and 4 physiological characters, and the results showed that the selection index was formed based on multivariate analysis from 9 characters. Through index selection, Syn_2-2 (0.79), Syn_2-15 (0.85) and Syn_2-16 (0.97) were considered as drought stress adaptive lines. Therefore, the 3 lines can be recommended in the synthetic variety release process.

Keywords: abiotic stress, corn, multivariate analysis, principal component, secondary characters

Abbreviations: 1000SW: 1000 Seed Weight; ASI: Anthesis Silking Interval; DAP: Day After Planting; DFF: Days of Female Flowering; DMF: Days of Male Flowering; ED: Ear Diameter; EH: Ear Height; EL: Ear Length; LR: Leaf Rolling; NDL: Number of Dried Leaves; NL: Number of Leaves; PH: Plant Height; Pr: Productivity

INTRODUCTION

Maize (*Zea mays* L.) is an important feed and food in Indonesia. This commodity also is one of the main ingredients of industrial companies, which makes it the 3rd important cereal commodity in the world after wheat and rice (Bukhsh et al. 2012; Cooper et al. 2014). In Indonesia, maize production is considered good, reaching 30 million tons in 2018 (Agriculture Ministry 2018). However, as population growth increases, annual maize production also needs to further increase to meet the demand (Sah et al. 2020; Badr et al. 2020). Climate change negatively impacts the plant growth environment, such as drought, salinity, submergence, etc. (Raza et al. 2018). The prolonged temperature rise due to climate change induces drought stress, which in turn threatens the maize production stability (Fahad et al. 2017), and as a result, domestic production has failed to meet the demand. Therefore, the maize production problem in drought stress conditions should be solved to increase the maize yield.

Generally, water scarcity caused by limited water availability on agricultural land or plant inability to absorb water is a common drought stress factor (Farid et al. 2019). This stress can inhibit some plant morphology and physiological processes, such as cell division, cell development, nutrient transport and translocation, plant enzymatic process, plant metabolism, pollen sterility, and grain development, which affect the growth and yield of plants, including the maize (Silva et al. 2013; Fahad et al. 2017). Although maize is known to use water efficiently (Ghannoum 2009), a long period of drought stress, both at vegetative stage and at the anthesis stage, will decrease production (Witt et al. 2012; Souza et al. 2013; Song et al. 2019; Sah et al. 2020). According to Monneveux et al. (2005) and Sah et al. (2020), drought stress can decrease maize yield by 17–60% in tropical areas. Song et al. (2019) also reported that the drought stress could decrease the maize yield up to 50% from 2013 to 2016. Therefore, this problem needs to be solved through, among others, developement of drought stress adapted maize variety.

Maize variety can be developed through hybridization and open-pollination. The hybrid is a popular variety in maize (Fromme et al. 2019; Kandel 2020) because it is relatively sensitive under stress conditions (Kutka 2011; Sharma et al. 2019). However, the synthetic variety is more adaptive under stress conditions, making it suitable for development (Kutka 2011; Freshley and Delgado-Serrano 2020). The adaptive variety produces good yield and growth characters in any environment, including stress conditions (Lin et al. 1986; Fadhli et al. 2020). To produce the variety possessing this trait, the combination of the yield supporting characters, known as secondary characters, must be studied. The yield is mostly comprised of polygenic traits Hence, secondary supporting characters can keep potential lines in any environment (Kassahun et al. 2013; Fellahi et al. 2018), especially under drought stress conditions. Sabouri et al. (2008), Saad et al. (2014), Fellahi et al. (2018), and Anshori et al. (2019) have reported the assessment of tolerance lines involving the secondary characters. Besides, according to Fadhli et al. (2020), using the secondary character in selecting adapted lines under drought stress was more effective. Therefore, these characters are important in selecting the adapted synthetic maize under drought stress.

Secondary characters can be obtained through morphology and physiology characterization. These combinations present strength that can be considered in a selection for adapted lines under stress conditions. Previous reports on this concept under drought stress have been made by Barik et al. (2019) on rice, Souza et al. (2013), and Sabagh et al. (2017) on maize. However, combining all secondary characters and yield requires a selection formula known as the selection index. This is the linear multivariate regression consisting of specific weighted criteria selection (Rajamani et al. 2016; Islam et al. 2017). Moreover, the index needs systematic analyses such as multivariate analysis to determine the fit of secondary characters and the weighting of its secondary characters. The success of this approach has been reported by Sabouri et al. (2008), Peternelli et al. (2017), Kose et al. (2018), Branković et al. (2018), Akbar et al. (2019), and Anshori et al. (2021). Therefore, applying multivariate analysis to develop a selection index based on morpho-physiological characters is useful in adaptive synthetic maize under drought stress. The objective of this study was to develop a selection index based on morpho-physiological characters and select the adapted synthetic maize lines under drought stress.

MATERIALS AND METHODS

The study was conducted in the Experimental Farm of Faculty of Agriculture, Hasanuddin University, Makassar from July to November 2017. This research was designed using a split-plot design with 3 replications where main plot watering (p) consisted of normal (p0) and stress irrigation (p1). Also, Subplots consisted of 6 genotypes (G): Syn 2-1 (G1), Syn 2-2 (G2), Syn 2-4 (G3), Syn 2-8 (G4), Syn 2-15 (G5), Syn 2-16 (G6) and 3 check varieties, i.e., bisma (G7), lamuru (G8) and sukmaraga (G9). According to the number of treatments, 18 combination was present and replicated 3 times, resulting in 54 experimental units while the plotting area for experimental unit size was 3bm x 3.5bm.

Experimental procedure

To prevent mildew disease, maize seeds used were given metalaxyl. Seeds (2) were placed in each planting hole and Carbofuran 30% was added with 15 kg ha^{-1} dosage to prevent pest infestation. Furthermore, each genotype treatment was planted in a 80 cm x 20 cm spacing, the thinning was done 14 days after planting (DAP), and fertilizer was applied 3 times. First fertilizer application (basal application) was applied seven days after planting at dosage of SP36 150 kg ha^{-1}, KCl 100 kg ha^{-1}, and Urea 70 kg ha^{-1}. The second fertilizer application was on 28 DAP with NPK 100 kg ha^{-1} and Urea 65 kg ha^{-1}, while, the third application was on 40 DAP with KCl 100 kg ha^{-1} and Urea 65 kg ha^{-1}. Also, irrigation was made with a water pump hosed by flooding the plots until it got to the height of the beds. Drought stress method was performed according to CIMMYT (Bänziger et al. 2000), where irrigation was stopped after the plants attained 40 DAP. Afterward, irrigation was avoided for the next 30 days and was given on the 70th day until physiological maturity. As for the normal condition, the irrigation was done by using the pump for the regular watering of fields. Plant maintenance included thinning, heaping, spraying, and weeding. Weeding was performed on 14 and 28 DAP and Insecticide application was adjusted according to the crop pests present in the experimental field.

Observation

Observations were done morphological and agronomical characters consisted of plant height, number of leaves, leaf angle, leaf width, number of dried leaves, days to female flowering, days to male flowering, Anthesis Silking Interval (ASI), days to harvesting, stem diameter, ear length, ear diameter, length of seeded ear, seed rendement, 1000 seed weight, and productivity. Meanwhile, the physiological character's observations were done on leaf age scoring, absorption level, reflection, stomata density, leaf chlorophyll index, and leaf roll scoring. The tools used for physiology character observations were lab miniature leaf streptic CI 7010 and chlorophyll meter SPAD 502.

Data analysis

Recapitulated data were subjected to analysis of variance and characters significantly affected were preceded into further analysis. Variance identification was performed using cluster analysis under normal and drought-stressed conditions. This was done in Rstudio 3.6.3 with factoextra (Kassambra and Mundt 2020) and dendextend (Galili 2015). Additionally, all characters showing significant interaction effect were subjected to analysis of stress tolerance index (STI) (Fernandez 1992), as follow:

$$STI = \frac{Yp \times Ys}{\bar{Y}p^2}$$

Where:

Yp : The character value of each line in normal conditions

Ys : The character value of each line in drought stress condition

$\bar{Y}p$: Average character values of all lines in normal conditions

After which they were analyzed by using a Pearson correlation analysis. This analysis was performed using Rstudio software with Agricolae package (Mendiburu 2020) and corrplot (Wei and Simko 2017) while, the selection index was formed through principal component analysis using STAR IRRI 2.0.1 (Anshori et al. 2019). Furthermore, the selection index applied to all genotypes was evaluated by comparing the synthetic maize lines index with the best comparing index.

RESULTS AND DISCUSSION

Analysis of variance indicated that morphological and physiological characters were significantly affected by genotypic variance and water condition (Table 1). However, not all characters were affected significantly by interaction variance. Morphological characters that were affected included plant height, number of leaves, number of dried leaves, days to female flowering, days to male flowering, Anthesis Silking Interval (ASI), ear height, ear diameter, ear length, leaf rolling, 1000 seed weight and productivity. Meanwhile, the physiological characters affected were reflection and chlorophyll. According to Al-Naggar et al. (2015), Mohamadi et al. (2017), Anshori et al. (2019) and Anshori et al. (2021), characters are significantly affected by genotype-environment interaction can exhibit response variance between genotype and growing environment factors. This is a base in distinguishing adapted or tolerant and sensitive maize genotypes under drought stress. A similar concept application was reported by Fadhli et al. (2020) on maize under drought stress, Anshori et al. (2021) on rice under salinity stress, and Akbar et al. (2019) on rice under drought stress. Therefore, all characters significantly affected by the interaction of genotype - water condition variance could be continued in further analysis.

Cluster analysis was the second approach to detecting interaction variance lines under normal and stress conditions. The results showed that synthetic maize genotype grouping experienced dynamic changes in both environments (Figure 1), and there was no straight line connecting the two dendrograms. Although on the 60% dissimilarity degree, both dendrograms had 3 cluster units with different group units in each. This shows that each genotype had a different response in every environment. Based on the result, cluster analysis was effective in depicting response variance in different growing environments. Some research has reported this by identifying relationships among objects towards many variables in several environments or models (Silva et al. 2013; Saad et al. 2014; Anshori et al. 2020). However, the simple dendrogram could not explain the specifically adapted trait under stress conditions. This proves that further analysis was required to evaluate the adaptability of synthetic maize under drought stress.

Table 1. Analysis of variance of morphological and physiological characters of a number of synthetic maize genotypes in varied environments

Characters	Irrigation (E)	Error a	Genotype (G)	G x E	Error b	CVa	CVb
Plant height	5998.52^{**}	44.34	698.23^{**}	193.06^{*}	79.04	4%	5%
Number of leaves	14.00^{**}	0.02	1.45^{**}	0.58^{**}	0.15	1%	4%
Number of dried leaves	27.45^{**}	0.07	0.49^{**}	0.20^{**}	0.06	13%	12%
Stem diameter	41.93^{*}	1.59	3.01^{*}	0.52ns	1.11	6%	5%
Days to female flowering	80.67^{*}	0.89	4.00^{**}	3.37^{*}	0.59	2%	1%
Days to male flowering	20.17^{**}	1.06	4.21^{*}	2.08^{**}	0.77	2%	2%
Anthesis Silking Interval (ASI)	20.17^{**}	0.17	1.27^{*}	1.83^{**}	0.51	15%	27%
Days of harvest	136.96^{*}	5.57	15.88^{*}	6.59ns	4.44	2%	2%
Ear height	1717.84^{*}	60.87	216.49^{**}	149.31^{*}	59.55	8%	8%
Ear diameter	80.87^{*}	1.17	5.88^{**}	5.11^{**}	1.13	5%	5%
Leaf angle	553.30^{**}	5.42	22.40^{*}	7.84ns	7.54	8%	10%
Leaf width	90852.41^{*}	2895.94	9762.18^{*}	3877.43ns	4268.73	12%	14%
Leaf aging	1.97^{**}	0.02	0.06^{**}	0.04ns	0.02	3%	5%
Absorption	1.97^{*}	0.02	0.06^{**}	0.04ns	0.02	18%	16%
Reflection	0.06^{**}	0.00	0.00^{**}	0.00^{*}	0.00	11%	8%
Stomata density	4129.96^{**}	36.92	1346.99^{*}	633.53ns	461.46	2%	8%
Leaf rolling	22.56^{**}	0.00	0.05^{**}	0.02^{*}	0.01	2%	3%
Leaf chlorophyll index	1244.23^{*}	56.25	297.95^{**}	166.79^{*}	70.89	1%	1%
Ear length	71.67^{*}	0.94	4.45^{**}	2.02^{**}	0.35	6%	4%
Seed rendement	365.50^{**}	1.52	6.70^{*}	5.01ns	2.96	2%	2%
1000 sed weight	8151.69^{*}	210.70	3634.07^{**}	403.89^{*}	143.89	4%	4%
Productivity	170.40^{**}	0.18	3.73^{**}	0.40^{**}	0.08	6%	4%

Note: CV: coefficient of variance; * significant at 5%; ** highly significant at 1% level; ns: not significant

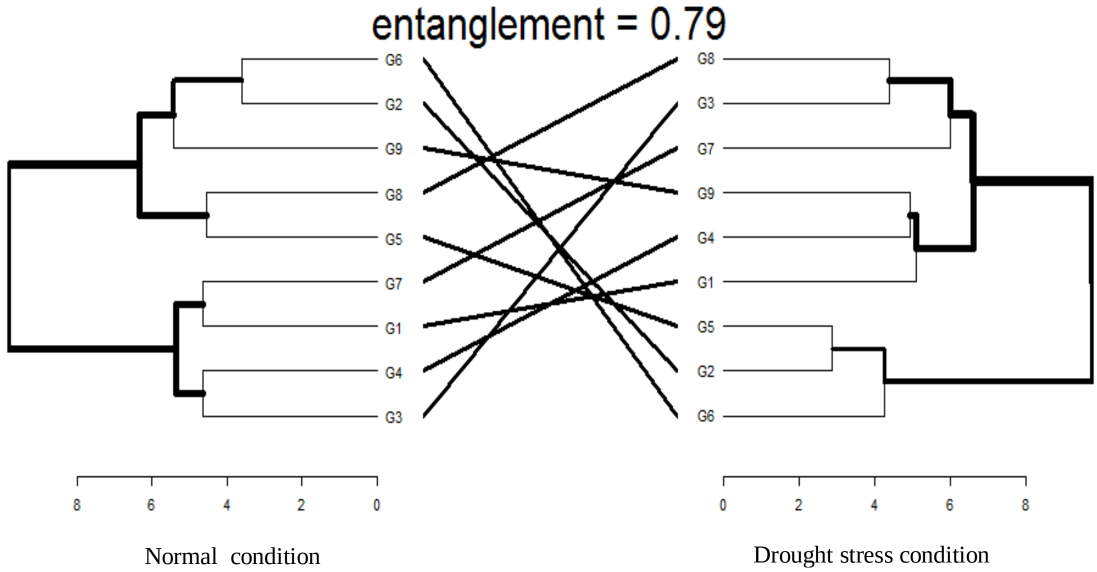

Figure 1. Cluster analysis of synthetic maize lines based on significant characters toward the interaction effect under normal and drought condition

The effectiveness of tolerance and adaptability can be evaluated with Stress Tolerance Index (STI). This detects tolerant lines under stress and has a midpoint benefit in considering the line's potential under normal and stress conditions (Anshori et al. 2019). Besides, STI considers the average responses of all genotypes under normal conditions. This is similar to a dynamic concept on the stability analysis used in assessing the stability lines (Hidayatullah et al. 2019; Kartina et al. 2019; Sitaresmi et al. 2019; Amzeri et al. 2020). Furthermore, the dynamic concept can assess the line's potential based on the average population responses (Lin et al. 1986), hence, the STI concept could be used in detecting adapted or tolerant lines. The application of the index to genotype tolerance and adaptability under environmental stress has been widely reported. Anshori et al. (2018) and Anshori et al. (2019) had previously applied this method in salinity-stressed rice, while, Kumar et al. (2015). A similar application has been made by Fadhli et al. (2020) on drought-stressed maize and Farid et al. (2019) on drought-stressed wheat. In addition, STI application on several characters had been reported by Anshori et al. (2019) and Fadhli et al. (2020). Therefore, STI application on characters significantly affected by the treatments was also used in this research.

Correlation analysis of STI values and the significantly affected characters showed that productivity was correlated positively to plant height (0.77), the number of leaves (0.76), ear height position (0.78), ear diameter (0.72), and 1000 seed weight (0.72). However, a negative sign was observed on the number of dried leaves (-0.84) (Figure 2). Some research has also reported these correlations, such as the correlation of ear diameter and number of leaves to productivity reported by Fadhli et al. (2020). Additionally, Ali et al. (2017) reported a significant positive correlation between productivity and ear diameter, while Yue et al. (2018) reported a significant correlation between yield and plant height. Leaf rolling has a negative correlation with the number of leaves (-0.89), plant height (-0.68), ear height (-0.68), and chlorophyll (-0.67) (Figure 2). This was due to its negative interpretation, where the more adapted the variety under drought, the less the leaf curling occurred (Efendi et al. 2019; Fadhli et al. 2020). Commonly, productivity is the main selection character, but various research was based on drought stress tolerance determination on leaf rolling (Obeng-Bio et al. 2011; Baret et al. 2018; Efendi et al. 2019). According to correlation analysis, an indirect correlation was discovered between leaf rolling and productivity in drought stress. This was proven in plant height, number of leaves, and ear height, significantly correlated with both characters. Furthermore, this indicated that the combination of these characters can increase drought selection accuracy. Therefore, the characters need to be combined in a selection index, and this can be analyzed through principal component analysis. Anshori et al. (2019), Akbar et al. (2019), Alsabah et al. (2019), and Anshori et al. (2021) had reported the index formation in this analysis.

Principal Component Analysis (PCA) result showed that 3 PC depicted STI characters (Table 2). This determination was based on the early PC that attained 0.8 cumulative variances (CV) (Jolliffe 2002). Based on CV value, PC1 to PC3 were determined as the potential candidates on the weighting index. Furthermore, the PC1 was the most productive eigenvector compared to PC 2 and PC 3, making this PC the basis for the weighing index (Table 2). A similar trend was previously reported by Anshori et al. (2019), Akbar et al. (2019), and Anshori et al. (2021), where the formation of selection index weighting value was based on the largest eigenvector from the main characters. Despite this, PC1 had a negative value, but its eigenvector was still used as a base of the weighing index, as was applied by Anshori et al. (2021).

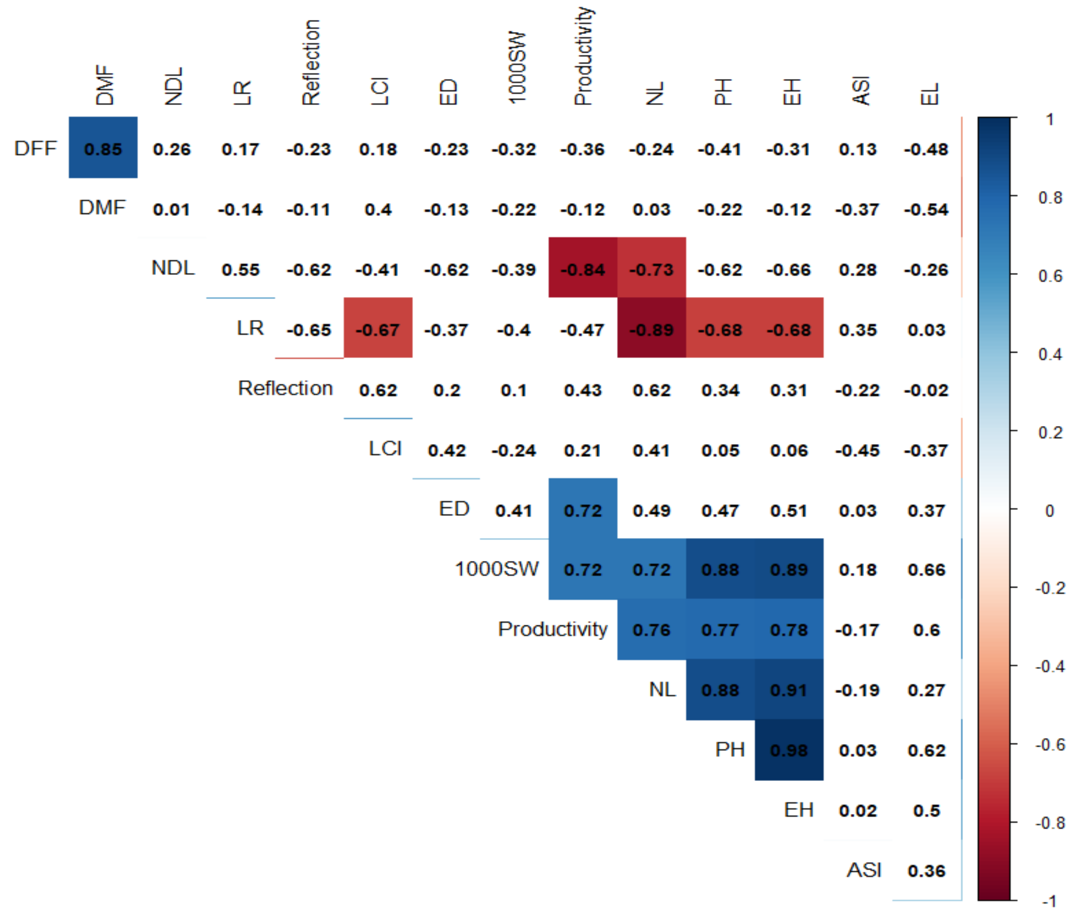

Figure 2. Heatmap based Pearson Correlation Analysis towards all STI Characters significant towards interaction (1000SW: 1000 seed weight, ASI: Anthesis silking interval, DFF: Days of female flowering, DMF: Days of male flowering, ED: Ear diameter, EH: Ear height, EL: Ear length, LCI: Leaf chlorophyll index, LR: Leaf rolling, NDL: Number of dried leaves, NL: Number of leaves, PH: Plant height)

According to Jolliffe (2002), positive and negative signs were limited to the variance direction of characters, making the eigenvector useful in positive conditions. However, due to their interpretation of tolerance, the number of leaves and leaf rolling were changed. Therefore, the selection index formed had the following formula:

Selection index = 0.358 plant height (PH) + 0.362 number of leaves (NL) - 0.315 number of dried leaves (NDL) + 0.352 ear height (EH) + 0.263 ear diameter (ED) - 0.291 leaf rolling (LR) + 0.189 leaf chlorophyll index (LCI) + 0.293 1000 seed weight (1000SW) + 0.346 productivity.

Various research has reported PCA application in finding a variation of an object and other variables (Jolliffe 2002; Mattjik and Sumertajaya 2011; Singh et al. 2015; Anshori et al. 2018; Fadhli et al. 2020). This analysis was effective in preventing multicollinearity or overlapped variance (Jolliffe 2002; Mattjik and Sumertajaya 2011), can increase selection index objectivity in genotype, and is linked with the index from Smith Hazel (Godshalk and Timothy 1988). Based on the research, determination of weighing value from PC eigenvector can affect priority characters towards drought stress. Productivity relatively has a low heritability value under abiotic stress (Kassahun et al. 2013; Fellahi et al. 2018), hence, the utilization of the characters with linear and larger variance can increase selection effectiveness under drought stress. Furthermore, Alsabah et al. (2019) reported that the variety of productive tillers was larger than productivity, and this was in line with path analysis results. According to Akbar et al. (2019) and Anshori et al. (2019), eigenvector application can be combined with path analysis. However, due to the small number of genotypes in the research, the analysis was considered unnecessary. Path analysis with fewer samples can cause multicollinearity (Olivoto et al. 2017; Sari et al. 2018), hence, this index application could increase the selection effectiveness of synthetic maize under drought stress. Based on the selection index, productivity does not dominate index variance but is the main character, as a result, the index requires adjustment. This has been reported by Anshori et al. (2019) on rice under salinity stress and Farid et al. (2021) on wheat under drought stress. Therefore, the adjusted selection index was formulated in this study.

Table 2. Principal component analysis based on STI Characters significant towards interaction

Variables	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
PH	-0.358	0.125	-0.134	0.219	-0.008	0.075	0.004	0.342	-0.191
NL	-0.362	-0.130	-0.099	0.218	-0.097	-0.029	-0.024	-0.132	-0.173
NDL	0.315	0.126	-0.103	0.277	-0.135	0.427	0.436	-0.409	-0.123
DFF	0.176	-0.302	-0.543	-0.154	-0.162	-0.256	0.089	-0.100	-0.497
DMF	0.053	-0.429	-0.507	-0.019	0.162	-0.109	0.189	0.179	0.361
ASI	0.050	0.349	-0.254	-0.169	-0.772	-0.072	-0.118	0.130	0.237
EH	-0.352	0.087	-0.246	0.182	-0.011	0.076	-0.275	0.168	0.039
ED	-0.263	-0.016	-0.006	-0.662	-0.057	0.392	-0.130	-0.195	-0.307
Reflection	-0.219	-0.220	0.387	0.113	-0.391	-0.529	0.180	-0.263	-0.050
LR	0.291	0.281	-0.047	-0.322	0.175	-0.312	-0.123	-0.131	0.245
LCI	-0.189	-0.429	0.137	-0.222	-0.220	0.332	0.267	0.047	0.462
EL	-0.198	0.422	-0.044	-0.162	0.086	-0.114	0.725	0.288	-0.071
1000SW	-0.293	0.235	-0.331	0.188	0.075	0.031	-0.040	-0.580	0.327
Productivity	-0.346	0.045	-0.040	-0.277	0.275	-0.262	0.110	-0.257	0.046
PV	0.478	0.219	0.104	0.071	0.057	0.041	0.019	0.012	0.000
CV	0.478	0.697	0.801	0.872	0.929	0.970	0.988	1.000	1.000
EigenValues	6.690	3.072	1.449	0.994	0.802	0.571	0.258	0.165	0.000

Notes: PV: proportion of variance, CV: cumulative of variance, 1000SW: 1000 seed weight, ASI: Anthesis silking interval, DFF: Days of female flowering, DMF: Days of male flowering, ED: Ear diameter, EH: Ear height, EL: Ear length, LCI: Leaf chlorophyll index, LR: Leaf rolling, NDL: Number of dried leaves, NL: Number of leaves, PH: Plant height

Table 3. STI Selection index on 9 synthetic maize genotypes

Genotype	PH	NL	NDL	EH	ED	LR	LCI	1000SW	Pr	Selection index
Syn_2-1	0.70	0.78	2.09	0.69	0.89	1.73	0.99	0.69	0.55	0.23
Syn_2-2	0.99	1.00	1.42	0.97	0.85	1.45	1.00	0.93	0.67	0.79
Syn_2-4	0.80	0.87	2.86	0.82	0.78	1.64	0.98	0.95	0.50	0.16
Syn_2-8	0.82	0.91	2.03	0.86	0.88	1.52	1.00	0.82	0.48	0.43
Syn_2-15	1.00	1.02	1.63	1.00	1.03	1.45	1.01	1.06	0.75	0.85
Syn_2-16	1.01	1.01	1.28	1.01	0.99	1.48	1.00	1.09	0.86	0.97
Bisma	0.90	0.86	2.78	0.86	0.83	1.59	0.98	0.92	0.48	0.23
Lamuru	0.96	0.89	1.87	0.98	0.92	1.70	0.97	1.08	0.68	0.61
Sukmaraga	0.84	0.86	2.46	0.85	0.94	1.58	1.00	0.85	0.53	0.32

Note: 1000SW: 1000 seed weight, ED: Ear diameter, EH: Ear height, LCI: Leaf chlorophyll index, LR: Leaf rolling, NDL: Number of dried leaves, NL: Number of leaves, PH: Plant height, Pr: Productivity

The adjusted concept is important because this analysis could avoid the overestimate interpretation (Anshori et al. 2019). The adjusted selection index can be conducted with some analysis. One of these adjusted analyses that could be conducted is correlation analysis. This analysis has been reported by Sabouri et al. (2008) and Chaudhary et al. (2017) on rice. Based on this, the combination of PCA weighting and correlation was performed in creating the selection index. The adjusted selection index was as follows:

Adjusted selection index = (0.358 x 0.77) PH + (0.362 x 0.76) NL – (0.315 x 0.85) NDL + (0.352 x 0.78) EH + (0.263 x 0.72) ED - 0.291 LR + 0.189 LCI + (0.293 x 0.72) 1000SW + 0.346 productivity.

Adjusted selection index = 0.276 PH+ 0.275 NL - 0.265 NDL +0.275 EH + 0.189 ED - 0.291 LR + 0.189 LCI + 0.211 1000SW+ 0.346 productivity.

The selection index result revealed 3 synthetic maize genotypes with a better index compared to Lamuru as check variety. These varieties were Syn_2-2 (0.79), Syn_2-15 (0.85), and Syn_2-16 (0.97). Lamuru is a composite variety with 7.6 tons ha^{-1} productivity and is tolerant to drought, making it frequently planted in areas with long dry months (Mustikawati and Yulia 2011; Aqil et al. 2012; Prasetyo and Amin 2019). According to Suwarno et al. (2009), the use of control/check varieties is the common method for best-selected lines and has been used in detecting the best rice line resistant to blast disease. Therefore, the 3 synthetic maize lines were recommended as advance line candidates under drought stress based on the research.

In conclusion, plant height, number of leaves, number of dried leaves, ear height, ear diameter, leaf rolling, chlorophyll, and 1000 seed weight were characters that affected synthetic maize productivity variance in drought stress conditions. Meanwhile, the principal component analysis resulted in Adjusted Selection Index = 0.276 plant height (PH) + 0.275 number of leaves (NL) - 0.265 number of dried leaves (NDL) +0.275 ear height (EH) + 0.189 ear diameter (ED) - 0.291 leaf rolling (LR) + 0.189 leaf chlorophyll index (LCI) + 0.211 1000 seed weight (1000SW) + 0.346 productivity. Through index selection, Syn_2-2, Syn_2-15 and Syn_2-16 were considered as drought stress adaptive lines. Therefore, these 3 lines can be recommended for further process as candidates of drought-tolerant varieties.

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