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Adaptation of several hybrid maize in West Nusa Tenggara drylands using modified plant spacing for optimal seed and biomass productions

Abstract. Maize is a crucial multipurpose strategic food crop in Indonesia. Land expansion employing dry land, row-space technology, and suitable varieties, is emerging as the solution to fulfill the rising need for seeds and biomass. The study was carried out from August to December using a factorial randomized block design consisting of two treatment factors, namely the treatment factor of 6 varieties and 2 row-spacings, to verify the new superior hybrid maize, which is adaptable in dry land Senayan village, Poto Tano sub-district, West Sumbawa district, and West Nusa Tenggara (NTB). The results showed that JH 37 and JH 29 varieties were adaptive to be developed in dry climate dryland areas for seed and biomass production using various narrow and wide planting space system. Jakarin, Bisi 18 and HJ 21 varieties could be planted in drylands by considering the planting space system for seed or biomass production, while the Nasa 29 variety was not recommended to be planted in drylands area for seed production, but could be used for biomass production by considering a wide planting space system such as Legowo system.

Keywords: Adaptive variety · Dry land · Hybrid · Planting space system

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Introduction

The demand for maize (Zea mays L.), a multipurpose strategic food crop that is significant for Indonesia's food, feed, and alternative bio sector, rises along with the country's population and number of farmers. With an increase of 2.24% per year, national maize productivity in 2019–2021 will remain low (16.85 t/ha), demonstrating the use of poor maize production technology (Wahyudin et al., 2015; PUSDATIN Ministry of Agriculture, 2020).

Maize is directed to develop on dry land with limited water sources in dry climates with proper water management so that the water needs for growth and seed filling of maize plants are sufficient. The development of maize on fertile land and readily available water sources is less competitive with other food crops like rice. According to Ritung et al. (2015), West Nusa Tenggara makes up about 1.72 million hectares of Indonesia's overall 144.47 million ha dry land area.

Limited water supplies, adaptable varieties, and inefficient farming techniques all have a significant impact on maize output in desert drylands. Water management, soil fertility, the use of new superior varieties (VUB), and the simplicity or convenience of a cultivation system are all important factors to consider when trying to increase maize output in arid climate drylands (Desyanto & Herman, 2014; Mulyani & Sarwani, 2013; Helviani et al., 2021). In order to increase land productivity and cropping index from one planting to two or three planting times, agricultural development in dryland climates utilizes the potential of available water resources with simple and affordable technology combined with the use of VUB and in situ organic matter management (Mulyani et al., 2014; Stewart, 2016; Sardiana et al., 2017). Hybrid maize productivity in dryland and dry climate is still low and constrained by suboptimal cultivation technology and inappropriate use of hybrid maize varieties, resulting in productivity far below potential yields (<10 t/ha). The average productivity of hybrid maize in West Nusa Tenggara is 6.7 t/ha (Statistics Indonesia, 2018). Test results for several hybrid maize varieties on dry land, namely Bima 20 URI around 8.72 t/ha, Nasa-29 around 8.51 t/ha, JH-37 around 9.32 t/ha, and Bima-14 around 8. 61 t/ha (Pratama et al., 2019; Triguna et al., 2021). According to Hipi (2008), the test results of several hybrid maize varieties were the production of Bima-2 Bantimurung 9.45 t/ha, Bima-3 Bantimurung 9.40 t/ha of dry shells. Hybrid maize production on rainfed paddy fields in NTB varieties Nasa 29 (10.07 t/ha), HJ 21 (11.1 t/ha), JH 37 (10.6 t/ha), and JH 45 (10.6 t/ha) (Erawati, 2020). Composite and hybrid maize production in North Lombok NTB varieties P4IS (3.59 t/ha), Gumarang (3.38 t/ha), Lamuru (4.60 t/ha) and NK 212 (4.30 t/ha) (Wahyudin et al., 2018).

The steps taken to overcome the problems of hybrid maize production in dry climate drylands from the aspect of variety types are adaptive quickly by verifying the production testing of several types of varieties in dry climate drylands. Varieties that have high production in dryland dry climate indicate that they are adaptive to this environment. Genotypes that have different limiting factors of tolerance to drought stress and plant potential are determined by how many seeds are formed in the growing environment (Suwardi & Azrai, 2013). Therefore, these types of varieties are very likely to be developed in dryland dry climate. To meet the increasing national demand for maize, it is necessary to increase production using new superior varieties and land expansion by utilizing dry climate drylands.

The objective of this research is to verify the suitability of new high-yielding varieties on dry climate drylands to serve as a basis for the selection and development of hybrid maize in West Sumbawa District, NTB using modification of plant space represented by planting space system.

Materials and Methods

The study was carried out from August to December 2021 in dry land of Senayan village, Poto Tano sub-district, West Sumbawa district, West Nusa Tenggara (NTB). The study employed two factors randomized completely block design, with the first factor was variety consist of six varieties: (Nasa 29), (JH 29), (JH 37), (Jakarin), (HJ 21), and (JH 29) and the second factor was cropping system comprises two cropping systems, i.e., the conventional system (population: 71,428 tan/ha, 70 x 20 cm spacing) and the Legowo system (population: 71,428 plant/ha, 90-50 x 20 cm spacing), were used in Bisi 18 and the treatment factor.

Planting used a Tugal system, 5 cm deep, with a spacing determined by the treatment, and covered with 2-5 t/ha of organic fertilizer. Maize plants were fertilized twice with inorganic fertilizer, the first with NPK (300 kg/ha) at 7 days after planting (DAP) and the second with urea (250 kg/ha) at 30-35 DAP. To prevent plant friability, each row of plants was hilled before weeding with a specific herbicide for maize plants at a concentration of 2 l/ha.

The initial weeding was done using selective post-emergence herbicides (Calaris) at dose of 2 l/ha when the maize plants were 7–10 DAP or before the first fertilization. When the soil is moist and the weeds have two to three leaves, the herbicide is administered. At 21 to 25 DAP, use a machine or a hoe to weed while hilling the plants to strengthen them to make irrigation easier.

Data observed were plant height (30 DAP, 110 DAP), cob height (110 DAP), leaf area index (ILD), biomass weight, harvest index (IP), rainfall, correlation between plant spacing and varieties, relationship between production and biomass, yield and yield components and soil analysis before the experiment.

Yield (t/ha) of each variety according to Firdaus et al. (2002) using the formula:

$$\text{Yield}\left(\frac{t}{ha}\right) = \frac{10000}{HA} \times \frac{100\text{-}MCS}{100\text{-}15} \times W \times 0.80$$

Description:
MCS = Moisture content of seeds at harvest
HA = Harvest area (m2)
15 = 15% seed moisture content
W = Weight of harvested peeled cob (kg)
0.80 = Mean of shelling percentage (yield)"

Data results were analyzed statistically using analysis of variance, then if significantly and very significantly different followed by Duncan's Multi Range Test (DMRT) at the 5% level.

Results and Discussion

Data from observations of climatic parameters made daily during the 5 months of research on Sumbawa Island showed that rainfall during the experiment was below 20 mm/day. At the beginning of planting in August, the rain was very scarce, but the humidity was still 70% might be caused by wind blow from Australia (Figure 1) Water need during the maize growing period is around 400-600 ml (Farhad et al. 2011) and that's a pretty much amount of water. Water for plant needs can be obtained from dew that forms in the morning. Some plants can utilize this dew for their water needs and it really depends on the genetic ability of each plant.

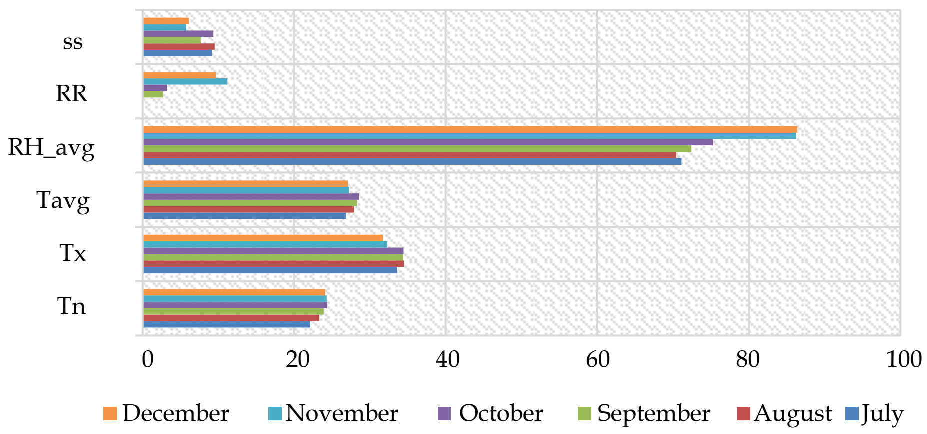

Figure 1. Sumbawa Island Average Monthly Climate Parameter Data

Description: Tn: Minimum temperature (°C); Tx: Maximum temperature (°C); Tavg: Average temperature (°C); RH_avg: Average humidity (%); RR: Rainfall (mm); ss: Length of sunshine (hours)

Getting varieties that can adapt to dry land is very beneficial because it will reduce production costs by eliminating the cost of too much watering. From the climatic parameter data diagram, it can also be seen that the Sumbawa region has high humidity which allows maize to utilize the vapor formed by utilizing its adventitious roots. Adventitious maize root function to support and defense against various biotic and abiotic stresses (Steffens et al., 2016).

Based on the results of soil analysis, it shows that the soil where the experiment was conducted belongs to the dust class with a pH of 7.61 so that the soil is neutral. Nitrogen, C-organic and P Bray-1 (ppm) contents were low, C/N ratio was medium and K2O content was very high. Exchangeable cations (me/100 g) of K was low, Ca and Mg were high, and Na was low. Base saturation was very high and CEC (me/100 g) was very low (Table 1).

The results showed that the plant height at 30 DAP in conventional system was not significantly different between varieties, while in Legowo system Jakarin variety was significantly different from Nasa 29 and JH 29 (Table 2). Conventional system at 30 DAP did not cause competition between plants to obtain nutrients, water and sunlight in various varieties, so they still showed the same performance at plant height. Legowo system for plant height of Jakarin variety was significantly different from Nasa 29 and JH 29, but not significantly different from the JH 37, HJ 21 and Bisi 18 varieties. This indicated that Legowo system caused competition between plants at 30 DAP so that plant height lower than the conventional system. The greater the plant spacing the lower the plant height, this indicated that any increase in plant spacing will reduce plant height (Yulisma, 2011). The competition of sunlight will make plant produce more auxin in their meristem tissue.

Table 1. Soil analysis before experiment, Poto Tano sub-district, West Sumbawa district, NTB.

Type of assignment	Assign-ment value	Valence
Texture		
Clay (%)	5	Dust
Dust (%)	64	
Sand (%)	31	
pH: Water (1:2:5)	7.61	Neutral
C-Organic (%)	0.92	Low
N Total (%)	0.10	Low
C/N	9	Medium
P Bray-1 (ppm)	9	Low
K2 O (ppm)	162	Very high
Exchangeable cations (me/100 g)		
K	0.35	Medium
Ca	15.85	High
Mg	2.37	High
Na	0.38	Low
CEC (me/100 g)	6.57	Very low
Base saturation (%)	100	Very high

Source: Soil, plant, fertilizer and water laboratory of BPTP South Sulawesi, 2021

Table 2. Mean agronomic variables at two planting systems and six hybrid maize varieties in Poto Tano district, West Sumbawa NTB.

Planting Space systems	Varieties	Plant height 30 DAP (cm)	Plant height 110 DAP (cm)	Cob Position Height110 DAP (cm)	Leaf area index 110 DAP (ILD)	Biomass(%) 110 DAP	Harvest index (HI)
70 x 20 cm (Conventional)	Nasa 29	61.00ab	175.33a-d	109.33ab	5.43a	66.81a	0.66a
	JH 29	61.93ab	195.40a	124.00a	4.99a	64.19ab	0.62ab
	JH 37	64.00a	184.73a-d	113.33ab	5.93a	61.57ab	0.61 ab
	Jakarin	61.00ab	178.66a-d	104.00ab	5.24a	62.97ab	0.63 ab
	HJ 21	56.60ab	177.66a-d	106.33ab	8.79a	63.93ab	0.64 ab
	Bisi 18	64.33a	190.33ab	106.67ab	5.91a	60.91ab	0.64 ab
(90-50) x 20 cm (Legowo)	Nasa 29	45.40b	193.33ab	102.33ab	5.19a	60.14ab	0.60 ab
	JH 29	46.40b	134.13d	96.33b	5.47a	57.67bc	0.57bc
	JH 37	55.46ab	167.73cd	98.67ab	5.41a	59.15abc	0.59abc
	Jakarin	66.60a	172bcd	99.00ab	5.15a	60.84ab	0.60 ab
	HJ 21	53.00ab	188.33abc	116.33ab	5.87a	52.71c	0.52c
	Bisi 18	61.87ab	185.66a-d	106.67ab	5.15a	60.91ab	0.60 ab
CV (%)		15.84	6.24	12.56	15.50	6.64	6.76

Description: Numbers followed by the same letter in the same column indicate not significantly different basedon Duncan's test at 5% level.

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Table 3. Average yield variables and yield components in two planting space systems using six new hybrid maize varieties in, Poto Tano district, West Sumbawa NTB.

Planting Space System	Varieties	Production (t/ha)	Cob length (cm)	Cob diameter (cm)	Number of kernel row/cob	Number of seed in row	100 seeds weight (g)
70 x 20 cm	Nasa 29	8.10d	17.27ab	4.39c	13.00d	35.93	33.33a-d
	JH 29	9.92ab	18.31a	4.90a	16.86a	30.03	30.33cd
	JH 37	10.37a	16.27b	4.70ab	15.13bc	33.83	26.66d
	Jakarin	9.28abc	17.23ab	4.85a	14.75bc	33.86	35.33a
	HJ 21	8.81bcd	16.91ab	4.91a	14.80bc	3496	35.33a
	Bisi 18	8.65cd	17.57ab	4.76a	15.46bc	35.9	30.33cd
(90-50) x 20 cm	Nasa 29	8.1d	17.01ab	4.39c	13.20d	37.7	33.00a-d
	JH 29	9.68abc	17.43ab	4.91a	16.06ab	36.33	31.00bcd
	JH 37	9.97ab	17.03ab	4.73a	15.06bc	34.96	33.33a-d
	Jakarin	9.52abc	17.46ab	4.78a	15.55bc	33.7	34.66ab
	HJ 21	9.39abc	17.10ab	4.89a	14.46c	33.8	34.33abc
	Bisi 18	9.46abc	17.33ab	4.65abc	16.00ab	36.13	31.33a-d
CV (%)		6.8	4.68	3.46	4.63	4.96	6.7

Description: Numbers followed by the same letter in the same column indicate not significantly different basedon Duncan's test at 5% level.

Plant height and cob height at 110 DAP showed that in conventional system was not significantly different between various varieties, while in Legowo system for the JH 29 variety was significantly different from the Nasa 29 and HJ 21 varieties, the cob height in conventional system and Legowo system were not significantly different between various varieties, but the JH 29 variety was significantly different in both of planting systems. This showed that inLegowo system there was a plant gap so that the level of water evaporation is higher than the conventional system which affected Nasa 29 and JH 29 varieties.

High water evaporation affects the availability of water in the soil that can affect plant growth. Plant height is strongly influenced by the level of competition between plants, especially competition for water, sunlight and growing space. The narrower spacing, the higher compe-tition between plants (Aisah & Herlina, 2018).

Biomass weight and harvest index are interrelated in determining the ability of plants to yield. Harvest index is the ratio of seed dry weight yield to total plant dry weight yield (Wahyudin et al., 2015). Table 2 showed biomass weight and harvest index (HI) of all varieties in conventional system were not significantly different, but when using Legowo system the biomass weight of HJ 21 varieties was significantly different from Nasa 29 and Bisi 18 varieties, while the harvest index (HI) of HJ 21 variety was significantly different from Nasa 29, Jakarin and Bisi 18 varieties. This showed that plant growth of each variety was influenced by the growing environment (planting system) due to competition between plants for water, nutrients, and sunlight in addition to plant genetic factors. The competition for sunlight and water causes synergistic and antagonistic additive plant responses (Zhang et al., 2011). However, this is influenced by the type of plant, especially the type of leaves. The upright type leaves will get more sunlight than the flat type leaves at various population levels. Upright type leaves maize will utilize more sunlight for photosynthesis even at high populations. High production per unit area in certain populations can utilize the use of sunlight in the photosynthesis process optimally (Kartika, 2018).

Table 3 showed that the production of the JH 37 variety was significantly different from Nasa 29, HJ 21 and Bisi 18 varieties, but was not significantly different from the JH 29 and Jakarin varieties using conventional system, while using Logowo system JH 37 variety was significantly different from Nasa 29 variety and was not significantly different from other varieties. The highest production at both of spacing system was achieved by JH 37 variety (10.37 t/ha and 9.97 t/ha) at 15% moisture content. This indicated that JH 37 variety in both spacing systems was superior to other varieties tested in dry climate dryland. JH 37 variety in dry climate dryland has high production and was able to adapt to drought stress morphologically and physiologically by optimally utilizing limited water and sunlight energy. Plants that can adapt to changes in irradiation by modifying morphology and physiology, will use available sunlight energy efficiently (Koike, 2013), so it has high yield potential even at high populations.

The cob length of JH 37 variety in conventional system was significantly different from JH 29 variety, but not significantly different from other varieties. The cob diameter of the Nasa 29 variety was significantly different from other varieties in conventional system, while the Legowo system was not significantly different from Bisi 18 variety. The cob length of various varieties in different spacing varies greatly, it is influenced by the environment (water, nutrients, sunlight) and genetics. Maize growth and production are strongly influenced by many factors such as variety type and spacing/population level (Yulisma, 2011). Cob length is closely related to the utilization of sunlight in the photosynthesis process, which are transmitted to the cob formation of various population levels that cause different cob sizes.

The number of row seeds per cob of Nasa 29 variety was significantly different from other varieties in both spacing systems, while the number of seeds per row was not significantly different. The number of rows per cob of Nasa 29 variety has fewer than other varieties and this is influenced by genetic factors. The number of seeds in addition to being influenced by genetic factors is also influenced by plant condition during the pollination phase.

Plants under drought stress during the pollination phase cause wilt, so that pollen is reduced and as a result decreasing in seed formation. The number of seed row per cob and the number of seeds in a row are strongly influenced in addition to the type of variety/genetic and environmental factors also influenced by the plant condition during the pollination phase. The optimal pollination phase will produce the maximum number of seed rows per cob and the number of seeds in a row according to the type of variety (Suwardi et al., 2020).

The 100 seed weight of the JH 37 variety was significantly different from the Jakarin and HJ 21 varieties but was not significantly different from the Nasa 29 and JH 29 varieties in conventional system. The weight of 100 seeds of all varieties was not significantly different using Logowo System. This showed that the planting space system, genetic factors and the availability of water for plant metabolic processes during photosynthesis also affect the weight of 100 seeds. Plants that occur drought will experience leaf rolling which results in inhibition of the photosynthesis process. Seed weights apart from genetic factors is also influenced by the ability of leaves during the photosynthesis process if there is a disturbance in the absorption of sunlight, the process is disrupted so that the results of photosynthesis transmitted to the seeds are reduced (Suwardi et al., 2020).

The correlation value between two characters in a certain spacing allows us to choose the best spacing for the best increase in maize production in drylands such as in NTB. The results of the correlation analysis between characters in the two planting space system conditions showed that in the dry environment using conventional system, production characters were negatively and significantly correlated to biomass characters, harvest index and plant height at 100 DAP and positively and significantly correlated to cob length, cob diameter, number of rows per cob and plant height at 30 DAP, while in Legowo system, production characters were negatively and significantly correlated to biomass characters, harvest index and 100 seeds weight and significantly positively correlated to the number of row seed per cob (Table 4).

Biomass characters were significantly positively correlated to harvest index under both planting space system conditions, significantly negatively correlated to cob diameter at Legowo system, and significantly negatively correlated to 100 seeds weight at conventional system. The two important characters of production and biomass were found to be negatively correlated to each other, but highly significant in Legowo system, which means that the greater the spacing, the higher the seed production, but the lower the biomass yield. Positive and significant character correlation were between cob length to cob diameter and number of seeds per row, cob diameter to number of seed row per cob, plant height at 30 DAP and leaf area index, number of rows of seeds to plant height at 100 DAP and cob position height at 100 DAP, plant height at 30 DAP to leaf area index and plant height at 100 DAP to cob position height at 100 DAP.

Table 4. Correlation between parameters under two planting space systems of new hybrid maize varieties

		BIO	HI	W100	CL	CD	NRC	NSR	PH30	PH100	CPH100	LAI
PROD	70	-0.242	-0.2485	0.0999	0.4597*	0.7712**	0.5957**	0.1141	0.5581**	-0.2498	0.2091	0.2861
	90	-0.5849**	-0.5497**	-0.4851*	0.07	0.3194	0.5375*	-0.1124	0.254	0.345	0.3428	0.1518
BIO	70		0.9987**	-0.4765*	-0.2825	-0.3011	0.2445	-0.2674	-0.0979	-0.2778	-0.3283	-0.141
	90		0.9967**	0.1449	-0.0802	-0.5691**	-0.3407	0.1824	-0.1386	0.016	0.0644	-0.1793
HI	70			-0.4781*	-0.2857	-0.3082	0.226	-0.259	-0.1054	-0.2691	-0.3314	-0.1566
	90			0.1579	-0.0829	-0.541*	-0.3192	0.1606	-0.1286	0.0279	0.0767	-0.1928
B100	70				-0.0622	-0.027	-0.3186	-0.2549	0.3609	0.1617	0.1934	0.2895
	90				-0.0701	0.099	-0.4512	-0.1327	0.0244	-0.479*	-0.462*	-0.0642
CL	70					0.5061*	0.088	0.5015*	0.1339	-0.117	-0.121	0.3056
	90					0.3682	0.411	0.7961**	0.2686	0.3804	0.3177	0.1762
CD	70						0.5003*	-0.009	0.4758*	-0.2348	0.2293	0.4665*
	90						0.4767*	0.0968	0.1291	0.2587	0.0728	-0.0249
NRC	70							-0.1659	0.3598	-0.4203	-0.0114	0.0761
	90							0.2855	0.1866	0.7484**	0.5439**	0.0555
NSR	70								-0.1919	0.2827	0.2192	-0.2576
	90								0.2322	0.3476	0.222	0.2008
PH30	70									0.1082	0.4131	0.5291*
	90									0.3197	-0.0298	0.4127
PH100	70										0.7624**	-0.1356
	90										0.8398**	-0.0246
CPH100	70											0.036
	90											-0.0584

Description: PROD : production, BIO : Biomass, HI : Harvest Index, W100: weight of 100 seeds, CL: Cob Length, CD : Cob Diameter, NRC : Number of Row per Cob, NSR: Number of Seed Row, PH30: Plant Height at 30 DAP, PH100: Plant Height at 100 DAP, CPH: Cob Position Height at 100DAP; LAI : Leaf Area Index

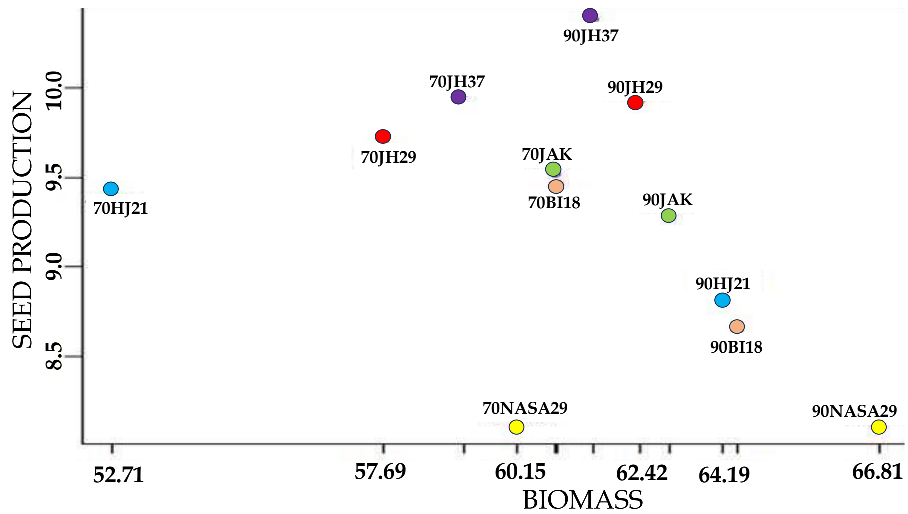

Figure 1. Correlation between seed production and biomass in two planting space systems using new improved maize varieties.

A negative correlation value between two characters indicates that the two characters have opposite activities. A high correlation value indicates how many varieties have characters whose action is opposite. The correlation of important characters between biomass and production showed that the correlation value was 58%, indicating that mostly tested varieties had opposite character actions (Table 4).

The two-way picture of the relationship between production and biomass characters with 2 planting space systems, showed that the JH 37 and JH 29 varieties experienced an increase in seed production and biomass simultaneously with the expansion of planting distances. In contrast, the Jakarin, Bisi and HJ 21 varieties experienced an increase in biomass and a decrease in production simultaneously with the increase in spacing, while Nasa 29 variety increased spacing only caused an increase in biomass with a fixed seed production (Figure 1).

Plant responsiveness to environmental changes is needed to determine the level of plant adaptability, so that plants that are responsive to changes in treatment that are adaptive to the environment. The results of this observation show that the JH 37 and JH 29 varieties are adaptive varieties in drylands that can produce seed optimally with wider plant spacing. The response of both varieties is positive to the increase in plant spacing where the increase in plant spacing increases biomass and production which is the goal in maize production in dry climate drylands such as in West Sumbawa District, NTB. Wide spacing was represented by Legowo system, while narrow spacing was represented by conventional system.

Conclusion

JH 37 and JH 29 varieties were adaptive to be developed in dry climates and dryland areas for seed and biomass production either in narrow or wide planting space systems. Jakarin, Bisi 18 and HJ 21 varieties could be planted in drylands by considering the planting space system for seed or biomass production, while the Nasa 29 variety was not recommended to be planted in drylands area for seed production but could be used for biomass production by considering a wide planting space system such as Legowo system.

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