BIODIVERSITAS
Volume 23, Number 5, May 2022
Pages: 2502-2511

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230530

Growth and yield of maize in *t'sen*, a local wisdom of planting in one planting hole, typical cropping pattern of West Timor's, Indonesia

YOHANNIS HARRY DIMU-HEO[1,2,♥], DIDIK INDRADEWA[1], EKA TARWACA SUSILO PUTRA[1], BENITO HERU PURWANTO[3]

[1]Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada. Jl. Flora No. 1, Bulaksumur, Sleman 55281, Yogyakarta, Indonesia
[2]Department of Food Crops and Horticulture, Politeknik Pertanian Negeri Kupang. Jl. Prof. Dr. Herman Johanes, Kupang 85361, East Nusa Tenggara, Indonesia.. Tel.:+62-380-881600, ♥email: yharryd@gmail.com; yohannis.heo@staff.politanikoe.ac.id
[3]Department of Soil, Faculty of Agriculture, Universitas Gadjah Mada. Jl. Flora No. 1, Bulaksumur, Sleman 55281, Yogyakarta, Indonesia

Manuscript received: 10 February 2022. Revision accepted: 24 April 2022.

Abstract. *Dimu-Heo YH, Indradewa D, Putra ETS, Purwanto BH. 2022. Growth and yield of maize in* t'sen*, a local wisdom of planting in one planting hole, typical cropping pattern of West Timor's, Indonesia. Biodiversitas 23: 2502-2511.* West Timor farmers have a strategy to anticipate the short rainy season and relatively low rainfall, namely planting maize, cowpeas, and pumpkin together in one planting hole, known as the local wisdom *t'sen* cropping pattern or *t'sen*. This study aims to study the growth and yield of maize and obtain maize varieties that are adaptive to the *t'sen*. The research was conducted at the experimental garden of the Faculty of Agriculture, Universitas Gadjah Mada (UGM), Yogyakarta, from April to August 2019. The study was arranged using a split-plot design with three replications. The *t'sen* as the main plot consisted of: monoculture maize, maize + cowpea, maize + pumpkin, maize + cowpea + pumpkin, while the varieties as sub-plots consisted of local varieties of maize from Kupang, Timor Tengah Selatan (TTS), Timor Tengah Utara (TTU), Malaka, and superior varieties Lamuru, and Pioneer p35. The results showed that all maize varieties experienced decreased growth and production in the *t'sen* compared to monoculture. The lowest decrease in growth and yield occurred in one planting hole of maize + cowpea, followed by maize + cowpea + pumpkin, and the highest was maize + pumpkin. The TTS and Kupang varieties have the highest average growth and production, which shows their resistance to competition and stress in *t'sen*.

Keywords: Cowpea, maize, marginal dryland, planting in one planting hole, pumpkin

Abbreviations: M+C: maize+cowpea in *t'sen* cropping pattern; M+C+P: maize+cowpea+yellow pumpkin in *t'sen* cropping pattern; M+P: maize+pumpkin in *t'sen* cropping pattern; GW1000: weight of 1000 grain; GWP: grain weight per plant; PDW: plant dry weight; Yield: yield per hectare

INTRODUCTION

The area of West Timor generally has a choppy, undulating, and hilly topography with a slope of 10-45%. The agricultural approach is shifting cultivation every 2 to 3 years, with a slash-and-burn system, especially during the land preparation stage (Kapa 2017). This condition causes agricultural land to be generally sensitive to erosion, low in nutrients (N, P, and K) and organic matter, and unstable soil aggregates (Basuki and de-Rosari 2017; Matheus et al. 2017). Climatologically, West Timor has a dry climate with a long dry season (8-9 months) and a short rainy season (3-4 months). The average number of rainy days is 96 days per year, with a total rainfall of 1760 mm per year, of which 64% of rainy days (62 days), and 70% of rainfall (1250 mm), occur in the rainy season, namely December-March (BPS NTT 2018; BPTP NTT 2018). This condition describes a period without rain for two weeks every month during the rainy season, disrupting plant growth and yields. During this time without rain, maize plants generally experience leaf curling, indicating that the plant lacks water.

In this relatively marginal environment, farmers in West Timor developed a distinctive maize cultivation technique, namely planting maize, cowpeas, and pumpkin simultaneously in one planting hole, which is acronymized as the "*salome*" (*satu lubang rame-rame*) cropping pattern, or in West Timorese (Dawan) language called "*t'sen tabua bola mese*" or "*t'sen*". The *t'sen* cropping pattern is a unique and extreme form of mixed cropping. Mixed cropping is planting a mixture of two or more different crop species on a land unit, simultaneously (Teshome, 2019). This cropping pattern is similar to Milpa and The Three Sisters, a cropping pattern that generally involves maize, beans and squash, which is an ancient way of growing maize introduced by indigenous Mesoamerican populations (Palacios-Rojas et al. 2020; Ngapo et al. 2021; Novotny et al. 2021). About 78% of the maize planted is generally of local varieties, while composite varieties Lamuru and hybrid varieties are 16% and 6%, respectively (Subagio and Agil 2013). The high use of local varieties is because they are more tolerant, their production is more stable in the face of marginal land stress, the shelf life of seeds is longer, they are resistant to warehouse pests, and result in good quality processed staple food (Hosang et al. 2010).

The socio-cultural cultivation of the *t'sen* cropping pattern is related to eating maize, beans, and pumpkins as the staple food for the community, especially in rural areas. The harvest is generally stored for a year for food security. Technically, planting is done by planting one to two maize, cowpea, and pumpkin seeds in one planting hole. The planting combinations can be maize + cowpea + pumpkin, maize + cowpea, or maize + pumpkin, with the spacing generally being comprehensive and not uniform. Maize planting is generally done once a year, at the beginning of the rainy season, where rainfall is the primary source of irrigation. This is done to reduce the risk of failure and be more efficient in utilizing the availability of rainwater, time, and labor. In their growth, maize and pumpkin plants will benefit from the nitrogen fixation of cowpea plants. Maize stalks can act as a support for cowpea, while pumpkin plants with larger leaf sizes can cover the soil surface, thereby reducing evaporation and suppressing weed growth. On the other hand, this condition will increase plant competition, especially for water and nutrients in the root zone.

Empirically mixed cropping has advantages over monocultures and requires adaptive research for its development (Silberg et al., 2017; Gaitán-Cremaschi et al. 2019; Rodriquez-Robayo et al. 2020; Tilman 2021). Therefore, the research aimed to study the effect of cropping patterns and varieties on the growth and yields of maize, and obtain maize varieties that are adaptive to the *t'sen* cropping pattern.

MATERIALS AND METHODS

Plant varieties

The study used six maize varieties, consisting of four local varieties of West Timor, one superior composite variety, and one superior hybrid variety. The local varieties are white grain maize from four districts with the highest maize production in West Timor, namely the local varieties of Kupang, Timor Tengah Selatan (TTS), Timor Tengah Utara (TTU), and Malaka, while the superior varieties used as comparisons were the composite Lamuru and the hybrid variety, Pioneer-p35. The cowpea variety used was a creeping growth type so that it would climb on the maize stalks for support.

Research site and design

The research was conducted in the experimental field of the Faculty of Agriculture, Gadjah Mada University, Yogyakarta, Indonesia, at the latitude and longitude coordinates are 70 48' 17.4" S and longitude 110^0 24' 46" E, respectively, from April to August 2019. The research site is 100 m above sea level. Weekly observations of temperature and humidity were recorded 3-14 weeks after planting, in the morning, afternoon, and evening. 45 x 50 cm polybags were used to simulate the relatively shallow (10-30 cm) soil conditions in West Timor, ± around 16 kg of planting media (a mixture of 7:1 soil:manure) was placed in the polybags to simulate the organic matter of slash-and-burn plant litter in land preparation carried out by farmers. The planting medium was analyzed for its physical and chemical characteristics before filling in the polybags.

This study did not include monoculture planting of cowpea and pumpkin, in line with the local production system in which the two crops were always intercropped with maize. However, research has focused on maize and how *t'sen* crop patterns affect maize growth and yield. Therefore, cowpea and pumpkin yield characteristics are used as additional data for a comprehensive assessment of the *t'sen* cropping pattern. The study used a split-plot design with three blocks as replication. The *t'sen* cropping pattern was the main plot consisting of monoculture maize (M), and a *t'sen* planting pattern (co-planting in one planting hole); maize + cowpea (M+C); maize + pumpkin (M+P); and maize + cowpea + pumpkin (M+C+P), while the varieties as sub-plots consisted of local varieties of maize Kupang, TTS, TTU, Malaka, Lamuru (composite), and Pioneer p35 (hybrid). The distance between polybags was 75 cm in rows and 100 cm between rows, with a distance between replications of 2.5 m.

According to the treatments, two seeds of each type of plant were planted in one planting hole. Two weeks after planting, thinning was done by leaving one plant for each type of plant in each planting hole. Plans were watered immediately after thinning and thereafter as and when needed, indicated by leaf curling, especially the upper leaves, and no fertilizers were. Both these practices simulated the field practices of farmers in West Timor. In order to maintain competition for growth resources (nutrients and water) and only sourced from planting media in polybags, pumpkin roots were pruned out of stems that propagated on the soil surface every two days.

Observation

Planting media and microclimate research site

Planting media was analyzed at the BPTP Laboratory in Yogyakarta, Indonesia, for texture, pH (H_2O), CEC, $C_{-organic}$, N_{-total}, $P_{-available}$, $K_{-available}$, $Na_{-available}$, $Ca_{-available}$, and $Mg_{-available}$. Microclimate was observations of weekly air temperature and humidity in the morning, noon, and afternoon.

Plant growth and yield

Plant growth as dry weight (PDW) was determined at nine weeks after planting (wap), and maize yield was determined as weight of grains per plant (GWP), the weight of 1000 grains (GW1000), and production ha-1 (Yield), in cowpea, seed production per hectare (Yield)and fruit production per hectare in pumpkin (Yield). The dry weight of the plant was calculated by drying in the oven at 90^0C until constant weight. The productivity of maize and cowpea seeds was calculated by weighing the yield of plant seeds after drying for two days in the sun until a moisture content of 12% was reached.

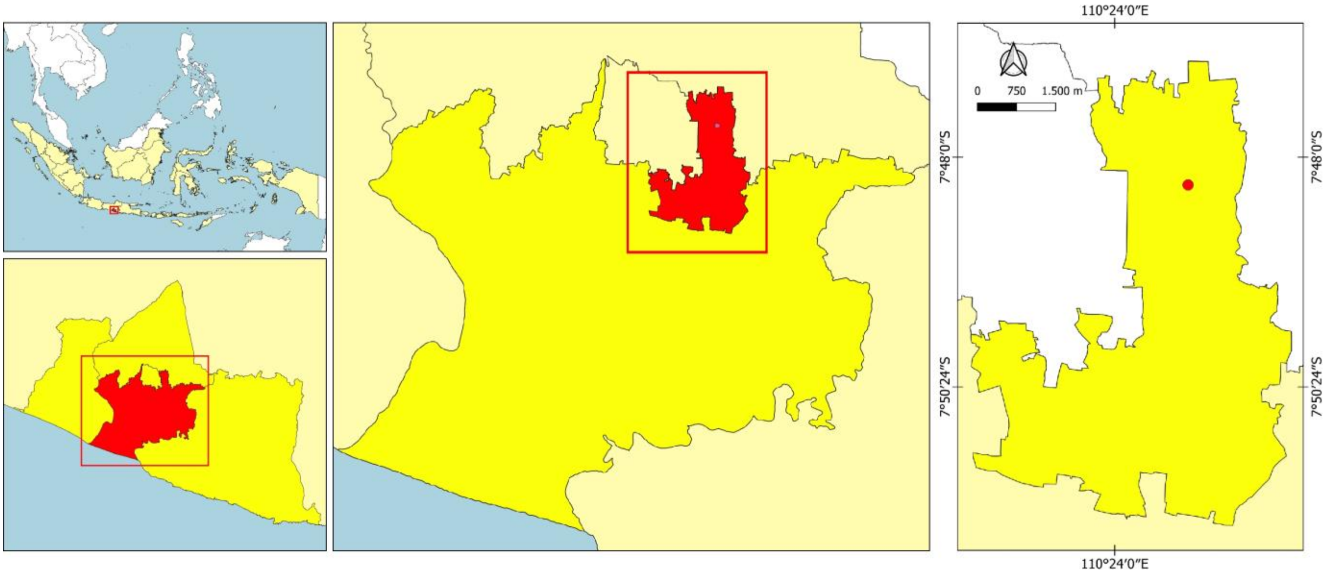


Figure 1. Geographical locations of the study area on the experimental field of the Faculty of Agriculture, Gadjah Mada University, Yogyakarta (latitude 7° 48’ 17.4” S and longitude 110° 24’ 46” E)

Selection of adaptive varieties in t’sen cropping patterns

Under mixed cropping conditions, plants experience stress in the form of abiotic stresses such as light, nutrients, water, light and temperature, and biotic stress due to the presence of other plants and pests, or even a high concentration of heavy metals (Choudhary et al. 2016; Dhar et al. 2013; Taberima et al. 2020; Wang et al. 2017). In this study, all plants were under stress due to the marginal conditions of the growing media (without additional fertilization) and the limited supply of water. However, under *t’sen* planting conditions, the plants experience relatively more stress than the monoculture cropping pattern due to cowpea and pumpkin. Therefore, in the interest of obtaining more tolerant varieties of the *t’sen* cropping pattern, it is assumed that the monoculture pattern with relatively less stress is the condition without stress, and the *t’sen* cropping pattern is the condition with stress. The selection of tolerant maize varieties was based on the seed yield of each maize variety. The tolerance level was calculated as Stress Tolerance Index (STI) (Fernandez 1992) and the Harmonic Index (HARM) (Jafari et al. 2009).

Data analysis

Data were statistically analyzed using a two-way Analysis of Variance (ANOVA), and Tukey's HSD evaluated the mean differences. Stepwise correlation and regression were used to identify the effect of the different parameters. All analysis was performed in SAS 9.4. The observational data of cowpea and yellow pumpkin were not analyzed for variance and were presented as complementary data.

RESULTS AND DISCUSSION

Physical and chemical characteristics of growing media and the environment microclimate during the study

The result of the laboratory analysis for the growing media used in this study indicated that the textural class of the growing media was sandy loam texture class. Further, the soil reaction (pH) was slightly acid, medium cation exchange capacity (CEC), low organic matter content, low total nitrogen content, high available phosphorus, medium exchangeable potassium, medium exchangeable sodium, medium exchangeable calcium, and medium available magnesium (Table 1). Microclimate observations during the study showed the average weekly air temperature was 27.6, 37.1, and 30.20C, with humidity of 65.3, 51.8, and 54.9%, in the morning, noon, and afternoon, respectively.

Table 1. Physical and chemical characteristics of growing media

Physical characteristic			Chemical characteristic								
Sand (%)	Silt (%)	Clay (%)	pH (H_2O)	CEC ($cmol^{(+)}kg^{-1}$)	Organic carbon (%)	N (%)	P (ppm)	K ($cmol^{(+)}kg^{-1}$)	Na ($cmol^{(+)}kg^{-1}$)	Ca ($cmol^{(+)}kg^{-1}$)	Mg ($cmol^{(+)}kg^{-1}$)
57.23	26.24	16.53	6.4	19.19	1.14	0.11	19	0.4	0.62	9.16	1.57

Growth, yield, and yield components of crops in the *t'sen* cropping pattern

Maize plant

The growth and yield characteristics of maize were significantly influenced by the interaction of the treatments (Table 2). The growth character of PDW, the character of the GWP, and the highest yield were obtained in a monoculture cropping pattern followed by a *t'sen* cropping pattern of M+C, M+C+P, and the lowest was in the *t'sen* cropping pattern M+P, while the highest GW1000 characters were produced in the *t'sen* cropping pattern M+C compared to monoculture and the *t'sen* cropping pattern M+C+P and M+P.

In monoculture, the PDW of maize plants differs between varieties. The TTS variety had the highest PDW that was different from all other varieties, followed by the Pioneer, Kupang, and Malaka varieties, which had relatively the same PDW and was higher than the Lamuru. The lowest was the TTU variety. Compared to monoculture, the *t'sen* pattern of M+C resulted in a decrease in PDW of all maize varieties, except the TTU variety, which produced a PDW that was relatively the same as the monoculture. In general, the response of maize varieties to the *t'sen* cropping pattern of M+C can be divided into two groups. The group that experienced a significant decrease in PDW was the Kupang, TTS, Malaka, Lamuru, and Pioneer varieties, and the group that did not experience a significant decrease in PDW was the TTU variety. All varieties of maize also showed a significant decrease in PDW in the *t'sen* cropping pattern M+P and M+C+P, and included in the group experienced a significant decrease in PDW.

T'sen cropping pattern M+C resulted in differences in PDW responses between maize varieties. The Kupang variety had the highest PDW that was different from all other varieties, followed by the TTU variety, which was different from the Malaka, TTS, and Pioneer varieties, having the same relative PDW lowest was the Lamuru variety. Meanwhile, the *t'sen* M+P cropping pattern also resulted in different PDW responses divided into three groups of maize varieties. The first group that experienced a significant decrease in PDW were local varieties of Kupang, TTS, TTU, and Malaka, the second group that did not experience a significant decrease in PDW, namely the Pioneer variety, and the third group experienced an increase in PDW although not significantly, namely the Lamuru variety.

The different PDW response was also observed in the *t'sen* pattern of M+C+P. The Kupang, TTS, and Pioneer varieties produced the same PDW and were higher than the TTU, Malaka, and Lamuru varieties. However, compared to the *t'sen* cropping pattern M+C+P, the *t'sen* cropping pattern M+C resulted in a significantly increased response of PDW in all local varieties, namely Kupang, TTS, TTU, Malaka, and Lamuru hybrid varieties. In contrast, the Pioneer hybrid variety did not produce a significant increase. Similar observations were also recorded in the *t'sen* pattern of M+C, which resulted in a significant increase of PDW in all varieties, except the TTS variety, and Pioneer, which experienced an insignificant increase in PDW.

Differences in responses between varieties to cropping patterns were also seen in the GWP. In monoculture, the GWP differed between varieties. For example, the TTS and Kupang varieties produced relatively the same GWP, significantly higher than the Pioneer, Lamuru, Malaka, and TTU varieties. However, planting in one planting hole in *t'sen* cropping patterns M+C, M+P, and M+C+P resulted in differences in the response of GWP in all maize varieties. In general, the responses of maize varieties when planting in *t'sen* cropping patterns can be divided into two groups. The first group which experienced a significant decrease was the varieties of TTS and Kupang, and the second group which did not experience a significant decline was the varieties of Pioneer, Lamuru, Malaka, and TTU.

The *t'sen* pattern M+C resulted in differences in GWP between maize varieties. The TTS, Kupang, and Lamuru varieties produced relatively the same GWP and were significantly higher than the TTU, Lamuru, and Malaka varieties. Compared to the *t'sen* pattern of M+C, the *t'sen* pattern of M+P resulted in a significant decrease in GWP in the TTS and Pioneer varieties, while the Kupang, TTU, Malaka, and Lamuru varieties did not experience a decrease in GWP. The response to differences in GWP between varieties was also seen in the *t'sen* pattern of M+C+P. The Kupang and TTS varieties produced relatively the same GWP and were significantly higher than the TTU, Malaka, Lamuru, and Pioneer varieties. The yield character of GWP in the *t'sen* M+C+P cropping pattern was relatively the same as the GWP for each variety in the M+C pattern because it experienced an insignificant decrease. A non-significant decreasing trend was also seen for all varieties in the *t'sen* pattern of M+P, except the TTS variety, which resulted in a significant decrease. This shows that the planting conditions of M+C+P, which are denser in plant population, did not result in a decrease in GWP of all maize varieties, compared to planting M+C and M+Pn, except for the TTS variety, where the GWP was lower in the M+P cropping pattern.

Under monoculture conditions, the GW1000 differed between varieties. However, all local varieties, namely Kupang, TTS, TTU, and Malaka, produced relatively the same GW1000, significantly higher than Lamuru and Pioneer varieties. Compared to monoculture, the *t'sen* pattern of M+C resulted in an increase in GW1000 for all maize varieties, although not significantly, except for the Malaka variety, which experienced a decrease in GW1000, although not significantly. The *t'sen* pattern M+P resulted in a decrease in GW1000 in all varieties, although it was not significant, except for the TTU and Malaka varieties, which experienced an increase in GW1000 although it was not significant. The *t'sen* pattern M+C+P resulted in a decrease in GW1000 for all varieties, although not significantly. The most significant decline occurred when maize was grown in the *t'sen* cropping pattern with pumpkin.

In the *t'sen* cropping pattern M+C, there was also a difference in GW1000 between varieties. The local varieties of Kupang, TTS, TTU, and Malaka, yielded a GW1000, which were relatively the same and significantly higher than the superior varieties of Lamuru and Pioneer.

The *t'sen* pattern M+P resulted in a difference in GW1000 of all maize varieties compared to the planting of the *t'sen* pattern M+C. The TTS varieties experienced a significant decrease, while the Kupang, TTU, Malaka, Lamuru, Lamuru, and Pioneer varieties did not experience a significant decrease in GW1000. The same trend also occurs in the conditions of planting M+C+P. All local varieties have a GW1000 the same or higher than the superior varieties. The GW1000 in the *t'sen* pattern M+C+P experienced an insignificant decrease and was relatively the same as that produced by each variety in the *t'sen* pattern of M+C. Therefore, different conditions occur when planting the *t'sen* cropping pattern M+P. Under these conditions, maize varieties can be grouped into two groups. The first group was the group that experienced an increase in GW1000 which was not significant, namely the Kupang, TTS, Malaka, and Pioneer varieties, and the second group experienced an insignificant increase in the GW1000, namely the TTU and Pioneer varieties.

In monoculture conditions, maize varieties resulted in differences in yield. The TTS and Kupang varieties produced relatively the exact yield, significantly higher than the Pioneer, Lamuru, Malaka, and TTU varieties. However, the *t'sen* pattern resulted in a different response to the decrease in Yield between each variety compared to the monoculture pattern. As a result, the TTS and Kupang varieties experienced a significant decrease, so the yield was lower than the monoculture. In contrast, the Pioneer, Lamuru, Malaka, and TTU varieties did not experience a significant decrease, so the yield of each variety was relatively the same as the Yield in monoculture.

Under the *t'sen* cropping pattern of M+C, the Yield of maize did not differ between TTS, Kupang, and Pioneer varieties but was significantly higher for TTU, Lamuru, and Malaka varieties. The *t'sen* pattern M+P resulted in a different Yield of all varieties compared to the *t'sen* pattern M+C. The TTS and Kupang varieties experienced a significant decrease in Yield, while the TTU, Malaka, Lamuru, and Pioneer varieties had relatively the exact yield.

The response to the difference in Yield between varieties was also seen in the planting conditions of the *t'sen* pattern of M+C+P. The Kupang and TTS varieties produced the exact yield and were significantly higher than the TTU, Malaka, Lamuru, and Pioneer varieties. Yield in the *t'sen* pattern of M+C+P was relatively the same as that of M+C, except for the Pioneer variety, which resulted in a significantly lower Yield. In the *t'sen* cropping pattern M+P, all varieties, except the TTS variety, produced Yield which was relatively the same as that produced in the *t'sen* cropping pattern M+C+P, while the yield of the TTS variety was significantly lower.

The results showed a positive linear relationship between Yield with PDW and GWP, while the GW1000 had an insignificant positive correlation with crop yields. Furthermore, the multiple regression analysis (Tabel 3) resulted in the following equation for predicting Yield of maize-based on PDW, GWP, and W1000 in the *t'sen* cropping pattern:

Yield = 0.9939^{ns} + 0.00002305 PDW^{**} + 0.02661 GWP^{**} + 0.00000546 $W1000^{ns}$; $R^2 = 0.99$, Adj $R^2 = 0.99$.

Cowpea and pumpkin plants

Table 4 shows the grain yield of cowpea and fruit yield in pumpkin, which were different in the *t'sen* cropping pattern and the maize varieties planted with them in one planting hole.

Grain yield per hectare of cowpea was different when planted with the *t'sen* cropping pattern M+C with all maize varieties. The higher yields were produced successively on planting with Malaka variety, followed by planting with TTU, Pioneer, Lamuru, and TTS varieties, and the lowest on planting with Kupang variety. On the other hand, the *t'sen* cropping pattern M+C+P resulted in a decreased yield of cowpea when planted with all varieties of maize compared to the M+C cropping pattern. In general, cowpea's grain production per hectare was higher in the *t'sen* cropping pattern M+C when planted with the Malaka variety and lowest in the *t'sen* cropping pattern M+C+P when planted with the Kupang variety.

Meanwhile, different yield tendencies were also seen in pumpkin's fruit yield per hectare. In the planting conditions with the *t'sen* cropping pattern of M+P, the highest yields were produced with Lamuru, followed by Malaka, TTU, Pioneer, and Kupang varieties, and the lowest was planted with TTS varieties. On the other hand, the *t'sen* cropping pattern of M+C+P resulted in a decreasing trend of pumpkin yields when planted with all varieties of maize, compared to the *t'sen* cropping pattern of M+P. In general, fruit yields per hectare of pumpkin tended to be higher in the *t'sen* cropping pattern M+P when planted with the Malaka variety, and the lowest was in the *t'sen* cropping pattern M+C+P when planted with the Kupang variety.

The level of tolerance of maize varieties to stress in the *t'sen* cropping pattern

The results showed differences in the tolerance level of maize varieties to stress in the *t'sen* cropping pattern, which was seen from the STI and HARM values (Figure 2).

Stress tolerance index (STI)

The high STI value was shown by all maize varieties in the *t'sen* cropping pattern M+C, followed by M+C+P, and the lowest was in the M+P cropping pattern. In the *t'sen* cropping pattern of M+C, and M+C+P, the TTS and Kupang varieties were categorized as tolerant varieties (STI>1.0), while other varieties were categorized as moderately tolerant (0.5>STI≤1.0). In the *t'sen* cropping pattern M+P, the TTS variety was categorized as a tolerant variety, while the other varieties were moderately tolerant.

Harmonic index (HARM)

The HARM value showed the same trend as the STI value; that is, the highest value was shown by all maize varieties in the *t'sen* cropping pattern M+C, followed by the M+C+P cropping pattern, and the lowest was the M+P cropping pattern. The TTS variety had the highest HARM value, followed by the Kupang variety compared to other varieties in all cropping patterns. The Malaka variety showed the lowest HARM value in all cropping patterns.

Table 2. Growth at nine wap, and yield characters of maize as affected by *t'sen* cropping system and maize varieties

***T'sen* cropping pattern**	**Maize varieties / growth and yield characters of maize**					
	Kupang	**TTS**	**TTU**	**Malaka**	**Lamuru**	**Pioner**
Plant dry weight (g plant^{-1})						
Maize (M)	200.87^{b}	235.37^{a}	168.74^{ef}	190.29^{cb}	183.01^{cd}	203.03^{b}
Maize + Cowpea (M+C)	171.97^{de}	135.75^{gh}	158.04^{f}	140.42^{g}	116.55^{ijk}	128.53^{ghi}
Maize + Pumpkin (M+P)	156.74^{f}	121.45^{ijk}	111.50^{jk}	108.68^{k}	118.65^{ijk}	125.04^{hi}
Maize + Cowpea + Pumpkin (M+C+P)	118.65^{ijk}	122.15^{ij}	76.21^{l}	81.94^{l}	69.64^{l}	121.06^{ijk}
Grain weight (g plant^{-1})						
Maize (M)	112.44^{a}	116.85^{a}	100.43^{b-f}	100.16^{b-g}	102.03^{bcd}	104.78^{b}
Maize + Cowpea (M+C)	104.65^{bc}	104.69^{b}	97.38^{c-g}	95.62^{efg}	96.14^{d-g}	103.17^{bc}
Maize + Pumpkin (M+P)	97.72^{c-g}	97.13^{c-g}	94.55^{fg}	94.51^{fg}	94.97^{fg}	95.03^{fg}
Maize + Cowpea + Pumpkin (M+C+P)	103.31^{bc}	101.60^{b-e}	94.77^{fg}	93.91^{g}	94.94^{fg}	95.10^{fg}
Weight of 1000 grain (g)						
Maize (M)	363.83^{a-d}	403.81^{ab}	348.34^{a-e}	418.83^{ab}	276.42^{e-h}	236.66^{fgh}
Maize + Cowpea (M+C)	364.13^{a-d}	423.27^{a}	373.40^{abc}	401.74^{ab}	284.32^{d-g}	245.16^{fgh}
Maize + Pumpkin (M+P)	313.68^{cde}	340.01^{b-e}	352.78^{a-e}	344.38^{a-e}	279.84^{e-h}	235.54^{fgh}
Maize + Cowpea + Pumpkin (M+C+P)	345.77^{a-e}	398.38^{ab}	316.23^{c-f}	372.61^{abc}	228.73^{gh}	201.62^{h}
Yield of grain (t ha^{-1})						
Maize (M)	3.00^{a}	3.12^{a}	2.68^{b-f}	2.67^{b-f}	2.72^{bcd}	2.79^{b}
Maize + Cowpea (M+C)	2.79^{b}	2.79^{b}	2.60^{c-g}	2.55^{efg}	2.56^{d-g}	2.75^{bc}
Maize + Pumpkin (M+P)	2.61^{c-g}	2.59^{c-g}	2.52^{fg}	2.52^{fg}	2.53^{fg}	2.53^{fg}
Maize + Cowpea + Pumpkin (M+C+P)	2.75^{bc}	2.71^{b-e}	2.53^{fg}	2.50^{g}	2.53^{fg}	2.54^{fg}

Note: The same letter in each column were not significantly different based on Tukey's test ($p>0.05$)

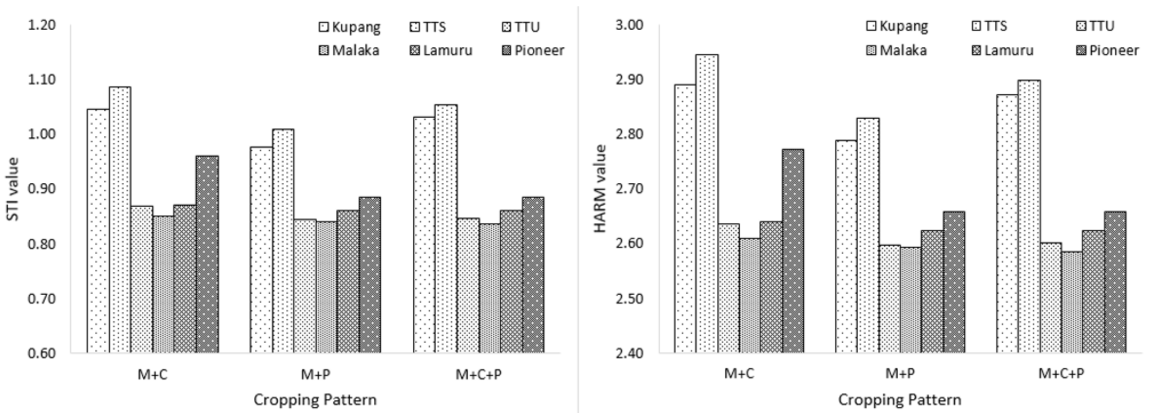
Table 3. Coefficient correlation between growth and yield characters of maize

Characters	**PDW**	**GWP**	**W1000**	**Yield**
PDW	1.00	0.78**	0.27^{ns}	0.78**
GWP		1.00	0.32^{ns}	0.99**
W1000			1.00	0.32^{ns}
Yield				1.00

Note: **, *: significant correlation at the 0.01, and 0.05 probability level, respectively; ns: non-significant

Table 4. The yield of cowpea and pumpkin, as affected by *t'sen* cropping system and maize varieties

***T'sen* cropping pattern**	**Maize varieties**					
	Kupang	**TTS**	**TTU**	**Malaka**	**Lamuru**	**Pioner**
Grain yield of cowpea (t ha^{-1})						
Maize + Cowpea (M+C)	0.922	1.034	1.190	1.212	1.071	1.078
Maize + Cowpea + Pumpkin (M+C+P)	0.806	0.867	0.999	1.043	0.960	0.883
Fruits yield of pumpkin (t ha^{-1})						
Maize + Pumpkin (M+P)	10.38	9.61	12.05	12.10	14.71	11.84
Maize + Cowpea + Pumpkin (M+C+P)	8.95	9.16	10.89	11.82	12.31	10.31



A B

Figure 2. Stress tolerance value of maize as affected by *t'sen* cropping pattern and varieties; A: STI, B: HARM

Discussion

Cultivation of the *t'sen* cropping pattern results in plant competition for growth resources. Higher competition, especially for underground resources, namely nutrients and water, while above-ground competition is relatively small because the three plants are morphologically arranged with different spatial strata. Maize plants occupy the top spatial strata because of their higher morphology, cowpea plants in the middle strata with their stems supported by the maize stalks, and pumpkin plants occupy the lowest spatial strata with their stems and leaves on the soil surface. The high competition below the soil surface occurs because plant roots will be in relatively the same zone due to planting in one planting hole, with relatively limited planting media conditions (in polybags), relatively low nutrient content, and limited water supply.

The results of the physical and chemical analysis of the growing media (Table 1), the absence of additional fertilization during plant growth, as well as the application of water when the plants experience leaf curl as a sign that the plant is starting to lack water, may not be fully representative but adequately describe the marginal conditions of the land. This is also reflected in the low yields of maize varieties Lamuru and Pioneer, namely 2.72 and 2.79 tons ha^{-1} on a monoculture cropping pattern, compared to the potential yields of 7.6 and 12.1 tons ha^{-1}, respectively.

Plant growth and development components of the t'sen cropping pattern

In environmental conditions such as marginal dry land, the presence of bean plants is expected to alleviate nutrient limitations, especially nitrogen, through its fixation ability. In contrast, the presence of pumpkin is expected to suppress evaporation through ground cover because of its stems and leaves that propagate along the soil surface. On the other hand, cowpea and pumpkin in the *t'sen* cropping pattern will increase plant populations and interactions between and within plants to obtain nutrients, water, light and space for growth. These plant interactions can be competitive, complementary, and supplementary (Duchene et al. 2017; Wang et al. 2017; Justes et al. 2021: Ren et al. 2021).

The highest PDW was shown by all maize varieties in the monoculture and decreased in the *t'sen* cropping pattern. The highest decrease in PDW was in the *t'sen* cropping pattern M+C+P shown by the Lamuru variety by 61.9%, the TTS variety by 48.4% in the M+P cropping pattern, and the Pioneer variety by 36.7% in the M+C cropping pattern. This condition shows that the Lamuru variety experiences higher stress than other varieties in the *t'sen* cropping pattern with marginal conditions. Marginal conditions of the growing media, cause competition for growth resources (such as nutrients and water) in the *t'sen* cropping pattern is higher than monoculture because it involves two or three plants. Competition between maize x cowpea, maize x pumpkin, and maize x cowpea x pumpkin, resulted in the number of growth resources obtained by each plant being smaller than maize in monoculture cultivation. Reduced nutrients as raw materials for the formation of plant tissue, while reduced water causes a physiological response to stomatal closure to reduce water loss and results in a reduction in the rate of photosynthesis, both of which cause a decrease in plant tissue growth which is characterized by a decrease in PDW. The higher PDW of maize in the monoculture cropping pattern is thought to be due to the lower plant population density, so that plants can more easily obtain resources such as nutrients, water, light, and growing space and are more profitable for their growth. These results are in line with several previous studies that low population density and the ability of maize varieties to respond to environmental conditions result in higher plant growth (Habte et al. 2016; Schwalbert et al. 2018).

Meanwhile, when *t'sen* cropping patterns were compared, higher PDW was shown in the *t'sen* cropping pattern M+P compared to M+C+P. This is presumably because the presence of cowpea in the *t'sen* cropping pattern M+C, and the *t'sen* cropping pattern M+C+P can increase the availability of nitrogen nutrients with their nitrogen fixation ability (Thilakarathna et al. 2016), although not yet fully able to meet the needs of the three crops (maize, cowpea, and pumpkin) to increase their growth in the *t'sen* planting pattern of M+C+P. This nitrogen fixation contributes to agricultural soil fertility, especially in conditions of low soil nitrogen availability, such as on marginal lands (Thilakarathna et al. 2016; Dong et al. 2018; Kermah et al. 2018; Kermah et al. 2019). However, the higher PDW in the M+P cropping pattern is due to the minor effect of plant density in the cropping pattern than the *t'sen* M+C+P cropping pattern, which affects the competition for resource utilization, and will affect plant growth. Therefore, decreasing PDW will ultimately reduce crop production per hectare due to the increasing number of seeds that fail to develop due to reduced production of reproductive organs (silks), and photosynthate for filling the seeds (Adee et al. 2016; Fernandez and Ciampitti 2021; Liu et al. 2020).

On the other hand, cowpea and pumpkin showed different growth tendencies in the *t'sen* cropping pattern. The PDW of cowpea plants was 10.2% higher in the *t'sen* M+C than the M+C+P cropping pattern, while the PDW of pumpkin plants was relatively the same in the M+C+P cropping pattern and M+C. This is presumably because the presence of cowpea in the cropping pattern of M+C and M+C+P can increase the availability of nitrogen nutrients to provide better growth for cowpeas and pumpkin in both *t'sen* patterns.

The yield of the components plant of the t'sen cropping pattern

The difference in PDW of the plant resulted in differences in the production character per hectare of the component of the *t'sen* cropping pattern. (Tables 2 and 4). The results showed that PDW correlated with maize yield. This is in line with da Silva et al. (2020), that grains are the result of the product of an accumulation of development and part of the allocation of biomass (PDW) to grains. The GWP of maize ranged from 100.2 - 112.4 g $plant^{-1}$ on monoculture and 93.9 - 104.7 g $plant^{-1}$ on *t'sen* cropping pattern. The GW1000 maize ranged from 245.2 - 423.3 g plant^{-1} on the *t'sen* M+C cropping pattern and 201.6 - 418.8 g plant^{-1} on the other cropping patterns. Maize production ranged from 2.7 - 3.1 t ha^{-1} on a monoculture cropping pattern and 2.5 - 2.7 t ha^{-1} on a *t'sen* cropping pattern. The same results were also reported by Hosang et al. (2010) that the weight of 1000 maize seeds of local varieties ranged from 250 - 400 g plant^{-1}, and crop production per hectare was between 2.7 - 3.0 t ha^{-1}. Meanwhile, for comparison, the average production per hectare of maize under the Three Sisters or Milpa cultivation system (a planting system similar to the *t'sen* system) was 2.93, and 1.80 tonnes ha^{-1} (Pleasant 2016; Lopez-Ridaura et al. 2021).

Generally, the GWP and the highest Yield per hectare of maize were produced in the monoculture and decreased in the *t'sen* cropping pattern. A decrease in PDW will ultimately reduce crop production per hectare due to the increasing number of grains that fail to develop due to reduced production of reproductive organs (silks), and photosynthate for filling the grains (Adee et al. 2016). The same results have been previously reported that grain weight per plant and seed production per hectare of maize in monocultures was higher than in intercropping (Kamara et al. 2019; Kermah et al. 2018). The decrease in GWP and Yield per hectare was shown by the TTS varieties, namely 16.9, 13.1, and 10.4%, respectively in the monoculture, and the *t'sen* cropping pattern M+P, M+C+P, and M+C. The opposite condition was shown in the GW1000, higher in the *t'sen* M+C cropping pattern than in the monoculture and other *t'sen* cropping patterns. The highest GW1000 was produced in the *t'sen* cropping pattern M+C, which were 2.1, 10.8, and 10.9% higher, respectively, than the monoculture, the *t'sen* M+C cropping pattern, and M+C+P. This is presumably due to the lower plant population density in the monoculture cropping pattern so that it is easier for plants to obtain resources such as nutrients and water, which will be more profitable for plant growth (Gutu 2017), and nitrogen fixation by cowpea in the cropping pattern with cowpea can increase soil nitrogen. This case can support the filling of maize grains to be more optimum while planting M+C+P. This increase in soil nitrogen has not increased the GW1000 due to the higher plant density. The TTS varieties are pretty competitive in acquiring these resources. Hosang et al. (2010) found that nitrogen fertilizer up to 90 kg ha^{-1} in maize cultivation in West Timor had no effect on seed production of maize but did affect the weight of 1000 maize grains. This study also showed that an increase in GW1000 in the pattern of M+C+P could not increase yield per hectare, presumably because grain production per hectare of maize was more related to the number of grains planted than the grain size. This is in line with Edmeades et al. (2017) that grain yield per plant is more strongly related to the number of grains per plant than weight per grain, especially when plants are under stress.

On the other hand, planting cowpeas and pumpkins, apart from increasing plant density, is also an additional benefit of the *t'sen* cropping pattern in terms of total production and yield diversity. When planted with all maize varieties in the *t'sen* cropping pattern, the two crops showed the exact yield characteristics. However, the cowpea plants showed a higher trend of seed production per hectare on M+C cultivation than M+C+P when planted with all maize varieties. This is thought to be due to the lower population density of the *t'sen* M+C cropping pattern than the M+C+P cropping pattern, so resource utilization is more profitable between the two crops. The same trend is also seen in pumpkin plants. Pumpkin plants showed higher fruit production per hectare in the M+P cropping pattern than M+C+P. This shows that the presence of cowpea with its fixation ability in the cropping pattern of *t'sen* M+C+P has not been able to produce nutrient dynamics that can increase pumpkin fruit production due to higher plant density conditions.

The level of tolerance of maize varieties to stress in the t'sen cropping pattern

The level of plant tolerance to stress accumulation in the *t'sen* cropping pattern was seen in the different values of STI and HARM (Figure 2). STI and HARM values are related to the ability of maize varieties to produce high production under stress conditions.

The results of this study indicate that the STI and HARM values can describe the ability of maize varieties to have high yields under the stress of the *t'sen* cropping pattern. Furthermore, the higher the STI and HARM values, the higher the yield of each maize variety. These results are in line with Efendi and Azrai's results (2015) that the stress tolerance index values of STI and HARM are highly correlated with maize grain yield and can be used to select maize varieties with high productivity under stress conditions.

In general, the results showed that the growth and production of all maize varieties decreased in the three *t'sen* cropping patterns compared to the monoculture. The cropping pattern of *t'sen* M+C resulted in decreased PDW and low yields. The planting pattern of M+C+P showed a moderate decrease, while the decrease in growth and high yields occurred in the planting pattern of *t'sen* M+P. There is a possibility that this is related to the presence of cowpea in the *t'sen* cropping pattern with its nitrogen fixation ability, thereby suppressing the decrease in growth and yield of the *t'sen* M+C cropping pattern, even in the M+C+P cropping pattern. The local varieties of TTS and Kupang have the highest average grain production per hectare compared to other varieties, which indicates that these two varieties are relatively more resistant to stress accumulation and competition in the *t'sen* cropping pattern. Although these two varieties have high STI stress tolerance and HARM values, they can be designated as adaptive varieties for *t'sen* cropping patterns. These two varieties can be used as genetic resources to further develop tolerance breeding programs on marginal land and intercropping patterns. The production of cowpea and pumpkin is an additional advantage obtained in the *t'sen* cropping pattern compared to the monoculture cropping pattern. The highest total production was produced in the *t'sen* M+C+P cropping pattern, followed by the M+C cropping pattern, and the lowest was M+P so that it can be used as an alternative cropping pattern in dry land and for further development.

ACKNOWLEDGEMENTS

The author would like to thank LPDP (Indonesian Endowment Fund for Education) for granting a 2017 Indonesian domestic lecturer scholarship (BUDI-DN), which funded doctoral study research, and the Faculty of Agriculture, Gadjah Mada University that helped to carry out this research.

REFERENCES

Adee E, Roozeboom K, Balboa GR, Schlegel A, Ciampitti IA. 2016. Drought-tolerant corn hybrids yield more in drought-stressed environments with no penalty in non-stressed environments. Front Plant Sci 7: 1534. DOI: 10.3389/fpls.2016.

Badan Pusat Statistik [BPS] NTT. 2018. Jumlah curah hujan menurut kabupaten/kota dan bulan. Central Agency on Statistics. https://ntt.bps.go.id/linkTableDinamis/view/id/389. [Indonesia]

Balai Pengkajian Teknologi Pertanaian [BPTP] NTT. 2018. Secuil info sumberdaya lahan NTT. Research and Assessment of Agricultural Technology. https://ntt.litbang.pertanian.go.id/index.php/450-secuilinfosumberdayalahanntt. [Indonesia]

Basuki T, de-Rosari B. 2017. Pemanfaatan kearifan lokal dan teknologi pertanian mendukung pembangunan pertanian wilayah In: Pasandaran E, Syakir M, Heriawan R, Yufdy MP (eds). Pembangunan Pertanian Wilayah Berbasis Kearifan Lokal dan Kemitraan. IAARD Press, Jakarta. [Indonesia]

Choudhary VK, Dixit A, Chauhan BS. 2016. Resource-use maximisation through legume intercropping with maize in the eastern Himalayan region of India. Crop Pasture Sci 67 (5): 508-519. DOI: 10.1071/CP15233.

da Silva MAL, e Silva PSL, de Oliveira VR, Sousa RP, da Silva J. 2020. Intercropping maize and cowpea cultivars: II. Dry grain yield. Revista Ciência Agronômica 51 (4): e20186552.

Dhar PC, Awal MA, Sultan MS, Rana MM, Sarker A. 2013. Interspecific competition, growth and productivity of maize and pea in intercropping mixture. Sci J Crop Sci 2 (10): 136-143.

Dong N, Tang MM, Zhang WP, Xing-Guo BXG, Wang Y, Peter CP, Li L. 2018. Temporal differentiation of crop growth as one of the drivers of intercropping yield advantage. Nat Sci 8 (1): 1-11. DOI: 10.1038/s41598-018-21414-w.

Duchene O, Vian JF, Celete F. 2017. Intercropping with legume for agroecological cropping systems: complementarity and facilitation processes and the importance of soil microorganisms. A review. Agriculture, Ecosystems and Environment, Elsevier Masson 10.1016/j.agee.2017.02.019. hal-02894041.

Edmeades GO, Trevisan W, Prasanna BM, Campos H. 2017. Tropical maize (*Zea mays* L.). In: Campos H, Caligari PDS (eds). Genetic Improvement of Tropical Crops. Springer, Cham. DOI: 10.1007/978-3-319-59819-2_3.

Efendi R, Azrai M. 2015. Kriteria indeks toleran jagung terhadap cekaman kekeringan dan nitrogen rendah. In: Muis A, Syafruddin, Bahtiar, Agil M (eds), Peningkatan Peran Penelitian dan Pengembangan Serelia Mendukung Swasembada Pangan; Prosiding Seminar Nasional Serelia. Badan Penelitian dan Pengembangan Pertanian, Maros. [Indonesia]

Fernandez GCJ. 1992. Effective selection criteria for assesing plant stress tolerance. In: Kuo CG (ed). Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress. AVRDC Publication. Taiwan, 13-16 August 1992.

Fernandez JA, Ciampitti IA. 2021. Corn grain weight: dependence upon nitrogen supply and source-sink relations. Kans Agric Exp Stn Res Rep 7 (5): 3. DOI: 10.4148/2378-5977.8073.

Gaitán-Cremaschi D, Klerkx L, Duncan J, Trienekens JH, Huenchuleo C, Dogliotti C, Contesse ME, Rossing WAH. 2019. Characterizing diversity of food systems in view of sustainability transitions. A review. Agron Sustain Dev 39 (1): 1-22. DOI: 10.1007/s13593-018-0550-2.

Gutu T. 2017. Performances of different varieties and population of soybean (*Glycine max* L.) under intercropping systems with maize (*Zea mays* L). Adv Life Sci Tech 53: 5-12.

Habte A, Kassa M, Sisay A. 2016. Maize (*Zea mays* L) - common bean (*Phaseolus vulgaris* L) intercropping response to population density of component crop in Wolaita zone southern Ethiopia. J Nat Sci Res 15 (6): 69-74.

Hosang EY, Shuterland MW, Dalgliesh NP, Whish JPM. 2010. Agronomic performance of landrace and certified seeds of maize in West Timor, Indonesia. In: Dove H, Culvenor RA (eds). Food Security from Sustainable Agriculture. Proceedings of the 15th Agronomy Conference. Australian Society of Agronomy, Lincoln New Zealand, 15-18 November 2010.

Jafari A, Paknejad F, Al-Ahmadi MJ. 2009. Evaluation of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids. Intl J Plant Prod 3 (4): 33-38.

Justes E, Bedoussac L, Dordas C, Frak E, Louarn G, Boudsocq S, Journet EP, Lithourgidis A, Pankou C, Zhang C, Carlsson G, Jensen ES, Watson CA, Li L. 2021. The 4C approach as a way to understand species interactions determining intercropping productivity. Front Agr Sci Eng. July 2021. DOI: 10.15302/J-FASE-2021414.

Kapa MJ, Gunawan T, Hardoyo SR. 2017. Sistem pertanian perladangan tebas bakar berbasis kearifan lokal pada wilayah bercurah hujan eratik di Timor Barat. Jurnal Pendidikan Geografi 4 (2): 10-19. [Indonesia]

Kamara YA, Tofa AI, Ademulegun T, Salomon R, Shehu H, Kamai N, Omoigui L. 2019. Maize-soybean intercropping for sustainable intensification of cereal-legume cropping systems in Northern Nigeria. Expl Agric 55 (1): 73-87. DOI: 10.1017/S0014479717000564.

Kermah M, Franke AC, Adjei-Nsiah S, Ahiabor BDK, Abaidoo RC, Giller EK. 2018. N_2-fixation and N contribution by grain legumes under different soil fertility status and cropping systems in the Guinea savanna of northern Ghana. Agric Ecosyst Environ 261: 201-210 DOI: 10.1016/j.agee.2017.08.028.

Kermah M, Franke AC, Ahiabor BDK, Adjei-Nsiah S, Abaidoo RC, Giller EK. 2019. Legume–maize rotation or relay? Options for ecological intensification of smallholder farms in the Guinea savanna of northern Ghana. Expl Agric 55 (5): 673-691. DOI: 10.1017/S0014479718000273.

Liu W, Hou P, Liu G, Yang Y, Gu0 X, Ming B, Xie R, Wnag K, Liu Y, Li S. 2020. Contribution of total dry matter and harvest index to maize grain yield - A multisource data analysis. Food Energy Secur 9 (4): e256. DOI: 10.1002/fes3.256.

Lopez-Ridaura S, Barba-Escoto L, Reyna-Ramirez CA, Sum C, Palacios-Rojas N, Gerard B. 2021. Maize intercropping in the Milpa system. Diversity, extent and importance for nutritional security in the Western Highlands of Guatemala. Nat Sci Rep 11 (1): 1-10. DOI: 10.1038/s41598-021-82784-2.

Matheus R, Basri M, Rompon MS, Neonufa N. 2017. Strategi pengelolaan pertanian lahan kering dalam meningkatkan ketahanan pangan di Nusa Tenggara Timur. Partner 22 (2): 529-541. DOI: 10.35726/jp.v22i2.246. [Indonesia]

Ngapo TM, Bilodeau P, Arcand Y, Charles MT, Diederichsen A, Germain I, Liu Q, MacKinnon S, Messiga AJ, Mondor M, Villeneuve S, Ziadi N, Gariepy S. 2021. Historical indigenous food preparation using produce of the three sisters intercropping system. Foods 10 (3): 524. DOI: 10.3390/foods10030524.

Novotny IP, Tittonell P, Fuentes-Ponce MH, Lopez-Ridaura S, Rossing WAH. 2021. The importance of the traditional milpa in food security and nutritional self-sufficiency in the highlands of Oaxaca, Mexico. PLoS ONE 16 (2): e0246281. DOI: 10.1371/journal.pone.0246281.

Palacios-Rojas N, McCulley L, Kaeppler M, Titcomb TJ, Gunaratna NS, Lopez-Ridaura S, Tanumihardjo SA. 2020. Mining maize diversity and improving its nutritional aspects within agro-food systems. Compr Rev Food Sci Food Saf 19 (4): 1809-1834. DOI: 10.1111/1541-4337.12552.

Pleasant JMT. 2016. Food yields and nutrient analyses of the three sisters: A haudenosaunee cropping system. Ethnobiol Lett 7 (1): 87-98. DOI: 0.14237/ebl.7.1.2016.721.

Ren Y, Zhang L, Yan M, Zhang Y, Chen Y, Palta JA, Zhang S. 2021. Effect of sowing proportion on above- and below-ground competition in maize–soybean intercrops. Nat Sci Rep 11 (1): 1-12. DOI: 10.1038/s41598-021-95242-w.

Rodriquez-Robayo KJ, Mendez-Lopez ME, Molina-Villegas A, Juarez L. 2020. What do we talk about when we talk about milpa? A conceptual approach to the significance, topics of research and impact of the Mayan Milpa system. J Rural Stud 77: 47-54. DOI: 10.1016/j.jrurstud.2020.04.029

Schwalbert R, Amado TJC, Horbe TAN, Stefanello LO, Assefa Y, Prasad PVV, Rice CW, Ciampitti IA. 2018. Corn yield response to plant density and nitrogen: spatial models and yield distribution. Agron J 110 (3): 970-982. DOI: 10.2134/agronj2017.07.0425.

Silberg TR, Richardson RB, Hockett M, Snapp SS. 2017. Maize-legume intercropping in central Malawi: determinants of practice. Intl J Agric Sustain 15 (6): 662-680. DOI: 10.1080/14735903.2017.1375070.

Subagio H, Aqil M. 2013. Pemetaan pengembangan verietas unggul jagung di lahan kering iklim kering. Seminar Nasional Serealia 2013. http://balitsereal.litbang.pertanian.go.id/ind/...2mu13.pdf. [Indonesia]

Taberima S, Prabawardani S, Sarwom R, Lyons G. 2020. Organic fertilizer applications improve the growth of vegetable crops and chemical properties in the tailings deposition area at Timika, Papua, Indonesia. Nusantara Biosci 12 (2): 134-142. DOI: 10.13057/nusbiosci/n120208.

Teshome S. 2019. Review on strategy of developing intercropping practices. Intl J Curr Res Acad Rev 7 (1): 61-67. DOI: 10.7176/JNSR/9-3-04.

Tilman D. 2020. Benefits of intensive agricultural intercropping. Nat Plants 6 (6): 604-605. DOI: 10.1038/s41477-020-0677-4.

Thilakarathna MS, McElroy MS, Chapagain T, Papadopoulos YA, Raizada MN. 2016. Belowground nitrogen transfer from legumes to non-legumes under managed herbaceous cropping systems. Agron Sustain Dev 36 (4): 1-16. DOI: 10.1007/s13593-016-0396-4.

Wang X, Deng X, Pu T, Song C, Yong T, Yang F, Sun X, Liu W, Yan Y, Du J, Liu J, Su K, Yang W. 2017. Contribution of interspecific interactions and phosphorus application to increasing soil phosphorus availability in relay intercropping systems. Field Crops Res 204: 12-22. DOI: 10.1016/j.fcr.2016.12.020.