YIELD, SEED QUALITY, AND FINANCIAL FEASIBILITY OF SOYBEAN INTERCROPPED WITH MAIZE IN THE ALFISOL DRY LAND

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Abstract. Intercropping of soybean with maize in the maize-producing areas is essential in expanding the soybean-harvested area in Indonesia. Such a study was carried out from March to July 2019 in the Alfisol dry land of Tuban, East Java using three soybean varieties (Argomulyo, Dena 1, and Dega 1) and cropping patterns of soybean and maize monoculture, intercropped of soybean + maize 0 day after soybean planting (DASP), soybean + maize 10 DASP, and soybean + maize 20 DASP. The soil had an alkaline pH (8) with a high content of Ca. No rainfall occurred 60 DASP, resulting in zero maize yield for both maize plantings at 10 and 20 DASP. The intercropping of soybean + maize 0 DASP was more beneficial relative to maize or soybean monoculture. Dena 1 variety showed the highest values of total land efficiency ratio (LER) (1.61), total equivalent to maize yield (7.18 t/ha), profit (IDR 18,878,000), and B/C ratio (1.92). Both cropping patterns produced a relatively similar 100-seed weight, and the seed quality was also suitable for seed production. Meanwhile, a slight and remarkable decrease in protein and fat content was noted, respectively for both cropping patterns. The results suggest that intercropping soybean with maize at 0 DASP is promising to be introduced in the Alfisol dry land.
Keywords: *light intensity, nutrient, profit, soybean variety*

Introduction

Efforts to increase soybean production in Indonesia are continously pushed by the government in order to achieve self-sufficiency. Introduction of the use of high-yielding soybean varieties adapted to different agro-ecological conditions and spesific cultivation technologies as well as expanding the harvested area have been intensively performed (Harsono et al., 2021). However, soybean is highly competitive with maize in terms of the land use, resulting in a gradual decrease in harvested area of soybean. During the period of 2014-2017, the soybean harvested area decreased from 614,000 ha to 355,000 ha, while it increased from 3.8 million ha to 5.5 million ha for maize (Statistics Indonesia, 2019). Therefore, introducing the intercropping pattern of soybean with maize, particularly in the maize production center is promising in terms of expanding the soybean harvested area.

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The intercropping practice of soybean and maize has been well adopted worldwide, particularly in China due to its high production and frequency of harvesting as well as the increase in radiation and land use efficiency (Mahallati et al., 2014; Yang et al., 2015; Liu et al., 2017). In general, intercropping maize and soybean gives a significant advantage in yield, economy, land utilization ratio and reducing soil nitrate nitrogen (N) accumulation (Zhang et al., 2015). Yu et al. (2015) revealed that the land equivalent ratio (LER) of this intercropping pattern is frequently around 1.22 and an average of 1.32 was reported in 90 similar studies (Xu et al., 2020). Improvement of land use efficiency in agriculture can be performed through a cropping pattern consisting of C3 and C4 plant types. Harsono et al. (2020) reported that intercropping soybean (C3) with maize (C4) using a model of maize-soybean strip intercropping (Du et al., 2018) in the dry land of Tuban, Indonesia gave LER values of 1.48-1.69 with an average total benefit of IDR 22.3 million/ha, which was much greater than the benefit obtained from maize monoculture (IDR 19.2 million/ha). In addition to economic benefit, legume intercropping patterns are also beneficial in terms of land sustainability, as they may reduce soil erosion and improve soil fertility through increasing the availability of N and P, better weed, pest and disease management, higher productivity and greater resource utilization (Li et al., 2013; Maitra et al., 2020; Thapa et al., 2021).

Light is an essential environmental factor for plant growth and development. Shading of soybean as a consequence of intercropping with maize may trigger the crop metabolic changes, decrease the photosynthetic activity and carbohydrate production, as well as potentially limit the crop growth and yield stability (Hussain et al., 2019). Soybean is known to be susceptible to shading effect (Liu et al., 2018; Wen et al., 2020). Harsono et al. (2020) noted that the shade level of soybean intercropped with maize was about 53-59% and 58-63% at 40 days and 60 days after planting, respectively, resulting in a yield decrease of 40-44%. Shade stress causes a decrease in photosynthetic rate through reducing the production of ATPs in photosystem II (PSII) reaction by blocking the electron flow rate (Valladares and Niinemets, 2008; Huang et al., 2018). As the consequences, morphological characteristics of soybean, biomass accumulation and distribution, and yield would be significantly affected (Liu et al., 2010; Yao et al., 2017). In this study, different planting times of maize (at the same time as soybean or a few days after soybean planting) will be evaluated in relation with the shading effects.

In addition to yield, intercropping of maize and soybean in particular may also influence the physicochemical characteristics of soybean seed or grain, thus they need to be investigated as quality of the products would be ultimately affected. In Indonesia, soybeans are mostly used for food, particularly are processed into tempe and tofu (83.7%), while the rest is used as ingredients for soy sauce, soy milk, and sprout (Ginting et al., 2021). In terms of supporting the seed availability, the quality of soybean produced under intercropping with maize for seed production purpose is also essential to be studied.

In order to expand the harvested area, growing soybean in sub-optimal land, such as Alfisol soil is becoming important as about 8.5 thousand ha of Alfisols exist in Indonesia (Sudaryono, 2002). Alfisols normally have a pH greater than 7 (alkaline), clay texture and low of soil nutrients and beneficial microorganisms. This type of soil contains a high amount of calcium as $CaCO_3$ (calcareous soil), which can interact with phosphor (P) and form a precipitate or an insoluble mineral as $Ca_3(PO4)_2$, resulting in low availability of P for uptake and adsorption by the plants (Clark and Baligar, 2000; Hopkins and Ellsworth, 2005). Alkaline condition commonly occurs in arid and semi-arid regions with small quantity of rainfall. However, the high pH of Alfisol may limit the soybean growth and

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development as the optimal pH for the crop is around 6.0 to 6.8 (Jayasumarta, 2015). The application of organic matters and soil microorganisms is reported to be effective to improve the soybean growth in alkaline soil (Febriati and Rahayu, 2019; Putri and Rahayu, 2019). Therefore, this study was performed to investigate the LER and competitive ability, light intensity, yield, and physicochemical characteristics of selected soybean varieties intercropped with maize at different planting times of maize in the Alfisol dry land, as well as the potential for seed production and the financial feasibility of such intercropping pattern. The objective of inserting soybean to maize under intercropping was to assess the land production and economic profit received by farmers.

Methodology

This study was carried out in the Alfisol dry land with dry climate in Merakurak Sub-district, Tuban Regency, East Java Province, Indonesia (*Figure 1*) during the dry season, started from March to July 2019.

Figure 1. *Study site of Merakurak Sub-district (GPS coordinate: S 6°52’38.6”, E 111°59’6.9”), Tuban Regency, East Java Province, Indonesia*

Maize is the main crop cultivated by farmers in this area following the cropping pattern of maize-maize or maize-groundnut. Instead of growing as monoculture for the second maize growing season (March-July), we introduced soybean to be intercropped with maize (S+M). This practice was intended to increase the production of land during the dry season. The trial applied a factorial randomized block design with three replicates. The first factor was intercropping maize and soybean where maize was planted at three planting times, *i.e.*, 1) At the same time as soybean planting (S+M 0 DASP), 2) 10 days after soybean planting (S+M 10 DASP), and 3) 20 days after soybean planting (S+M 20 DASP), as well as maize

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monoculture (Mono M), and soybean monoculture (Mono S). The second factor was soybean varieties, namely Argomulyo (large-seeded with 84-day maturity), Dena 1 (shade tolerant with large seed size and 78-day maturity), and Dega 1 (large-seeded with 73-day maturity). Each treatment was grown in a 9 m x 6 m plot size. The seeds of three soybean varieties belong to Foundation Seed (FS) obtained from Seed Production Unit of Indonesian Legumes and Tuber Crops Research Institute (Iletri). The commercial hybrid maize variety of NK 212 used in this trial was obtained from a local market. The plant spacing and plant arrangement for each cropping pattern is illustrated in *Figure 2*, while intercropping of soybean and maize in the field is presented in *Figure 3*.

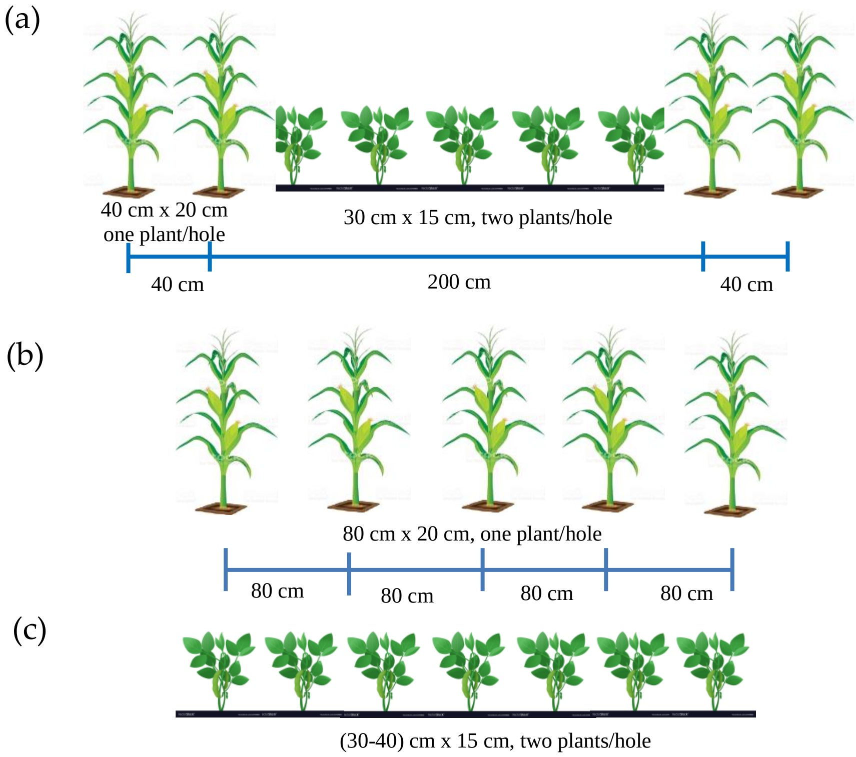

Figure 2. *Plant spacing and plant arrangement of (a) soybean intercropped with maize, (b) maize monoculture, and (c) soybean monoculture in Alfisol dry land in Tuban Regency*

(a) (b)

Figure 3. *Soybean intercropped with maize (S+M 0 DASP): (a) at 30 days after planting (b) at 60 days after planting in Alfisol dry land in Tuban Regency*

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The N, P, and K inorganic fertilizers for maize monoculture were applied two times. The first fertilization of 41.4 kg N + 54 kg P_2O_5 + 15 kg K_2O/ha was applied at 10 days after planting (DAP). The second fertilization of 82.8 kg N + 15 kg K_2O/ha was applied at 25 DAP. Meanwhile for soybean intercropped with maize, the N, P, and K inorganic fertilizers with a dosage of 13.8 kg N +18 kg P_2O_5 + 18 kg K_2O/ha was applied at 10 DAP. Soybean grown as monoculture treated with 23 kg N + 30 kg P_2O_5 + 30 kg K_2O/ha, which was applied at 10 DAP. This fertilizer application referred to the recommendation established by the local government agricultural office and calculated according to the number of population of each crop. All fertilizers were applied by putting the fertilizers in the furrows along the rows. The soybean crops in all treatments were rouged, both during vegetative and reproductive phases, following the procedure for soybean seed production (Kementan, 2016). After harvest, soybean grains were processed following the seed certification procedure.

Observations included the soil chemical properties before planting, distribution of rainfall during the growing season, shade level of maize toward soybean, seed yield of maize and soybean, land equivalent ratio (LER) and competitive indices (relative crowding coefficient, aggressivity value, actual yield loss, system productivity index), the yield components of soybean *i.e.* number of filled pods per plant and 100-seed weight, and chemical composition of soybean seed such as moisture, ash (gravimetric method) and fat contents (Soxtec direct extraction method) as referred to Indonesian Agency for National Standardization (1992), and protein content following a micro Kjeldahl method (AOAC, 2016). The seed quality analysis was conducted according to ISTA (2018). The seed moisture content and seed purity analysis were completed in five days after harvest, while the germination test was conducted at seven days after harvest. Sterile sand put in a plastic tray was used as a media for germination test of soybean seeds using 100 seeds for each replicate. Germination percentage was observed according to the criteria established by ISTA (2018). Analysis of soil chemical properties, seed chemical composition, and seed quality was conducted in the Soil Chemical Laboratory, Food Chemistry Laboratory, and Seed Testing Laboratory of Iletri, respectively. The data collected were statistically analyzed using Analysis of Variance (ANOVA), followed by Least Significant Differences (LSD) test to find out differences between treatments at a probability level of 0.05. Such statistical analysis was performed using a MSTAT-C software (Version 1.4, Michigan University).

The sunlight intensity was measured using a Digital Lux Meter (LX1330B model) at three sites: (1) above the soybean canopy which was not shaded by maize crop, (2) above two rows of soybean canopy closest to the double row of maize, and (3) above the three rows of soybean canopy in between the two double rows of maize. The measurement of light intensity above the soybean canopy either for shaded or non-shaded plants were conducted at the same height from the soil surface. The height of soybean canopy shaded by the maize plant was used as the standard height in positioning the light meter. Observations were done at three sites in each plot, and then these three values were averaged. The observation was conducted at 40 and 60 DAP for the entire plots.

Maize was considered as the main crop and soybean as an intercrop component. The grain yield of soybean from each treatment was converted to maize equivalent yield of mixed cropping system as follows (Agegnehu et al., 2006):

$$EYs = Ys\ x\ {}^{P1}/_{P2} \qquad \text{(Eq.1)}$$

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$$EYi = Ym + EYs \quad \text{(Eq.2)}$$

where EYs is maize equivalent yield of soybean (kg/ha), Ys: yield of soybean, P1: the price of soybean (IDR/kg), P2: the price of maize (IDR/kg), EYi: maize equivalent yield of intercropping pattern, and Ym: maize yield (kg/ha).

Land Equivalent Ratio (LER) was calculated using an equation introduced by Liu et al. (2018) as follows:

$$LER = LERm + LERs \quad \text{(Eq.3)}$$

where,

$$LERm = {}^{Yim}/_{Ym} \quad \text{(Eq.3a)}$$

$$LERs = {}^{Yis}/_{Ys} \quad \text{(Eq.3b)}$$

LER*m* and LER*s* is the LER value of maize and soybean, respectively. The LER is calculated based on the total land used in intercropping pattern. Y*im* and Y*m* is maize yield obtained from intercropping and monoculture, respectively, while Y*is* and Y*s* is the soybean yield obtained from intercropping and monoculture, respectively.

Stress intensity (SI) due to maize shading was calculated based on formula reported by Sundari et al. (2019):

$$SI\% = \left[1 - \left({}^{RYi}/_{RYm}\right)\right] x\ 100\% \quad \text{(Eq.4)}$$

where SI is stress intensity, RYi: average soybean yield in intercropping, RYm: average soybean yield in monoculture.

The competitiveness of each crop in each cropping pattern this study was assessed based on several parameters *i.e.*, relative crowding coefficient (K), aggressivity value (A), and actual yield loss (AYL). Relative crowding coefficient (K) was used to indicate the dominancy of one species relative to other species in a particular intercropping treatment. The K value was calculated based on formula used by Ghosh (2004):

$$Km = \frac{[Yim\ x\ Pis]}{[Ymm - Yim]}\ x\ Pim \quad \text{(Eq.5)}$$

$$Ks = \frac{[Yis\ x\ Pim]}{[Yms - Yis]}\ x\ Pis \quad \text{(Eq.6)}$$

where Km is relative dominancy of maize, Ks: relative dominancy of soybean, Yim: Yield of maize in intercropping, Yis: Yield of soybean in intercropping, Pim: maize area under intercropping (%), Pis: soybean area under intercropping (%), Ymm: Yield of maize in monoculture, Yis: Yield of soybean in monoculture.

The aggressivity (A) value was calculated based on formula applied by Agegnehu et al. (2006):

$$Am = \frac{Yim}{Ymm\ x\ Pim} - \frac{Yis}{Yms\ x\ Pis} \quad \text{(Eq.7)}$$

$$As = \frac{Yis}{Yms\ x\ Pis} - \frac{Yim}{Ymm\ x\ Pim} \quad \text{(Eq.8)}$$

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where Am is Aggressivity value of maize, As: Aggressivity value of soybean. Am >0, means that maize is dominant, As >0 means, that soybean is dominant.

The actual yield loss (AYL) was calculated based on formula used by Banik et al. (2000):

$$AYLi = AYLm - AYLs \quad \text{(Eq.9)}$$

where AYLi is actual yield loss in intercropping, AYLm: actual yield loss of maize, AYLs: actual yield loss of soybean. The AYLi >0, means that intercropping is beneficial, and conversely to AYL<0.

$$AYLm = \left[\left({}^{Yim}/_{Pim}\right)/\left({}^{Ymm}/_{Pmm}\right)\right] - 1 \quad \text{(Eq.10)}$$

$$AYLs = \left[\left({}^{Yis}/_{Pis}\right)/\left({}^{Yms}/_{Pms}\right)\right] - 1 \quad \text{(Eq.11)}$$

where Yim is yield of maize in intercropping, Pim: maize area under intercropping (%), Ymm: yield of maize in monoculture, Pmm: maize area under monoculture (%), Yis: yield of soybean in intercropping, Pis: soybean area under intercropping (%), Yms: yield of soybean in monoculture, Pms: soybean area under monoculture (%).

Analysis of financial farming feasibility was also performed for each cropping pattern. The financial farming feasibility was determined using a benefit-cost (B/C) ratio approach (Istriningsih and Dewi, 2015). B/C ratio measured the farming feasibility by comparing total benefit with total production cost of soybean-maize intercropping (Habib et al., 2019) using the equation as follows:

$${}^{B}/_{C}\,ratio = \frac{(TRm+TRs)-(TCm+TCs)}{(TCm+TCs)} \quad \text{(Eq.12)}$$

where B/C ratio is benefit-cost ratio, TRm = Total revenue of maize crop, TRs = Total revenue of soybean crop, TCm = Total production cost of maize crop, TCs = Total production cost of soybean crop. The B/C ratio >1 reflects that soybean-maize intercropping is profitable and feasible; B/C ratio =1 means that soybean-maize intercropping is at break-even point (BEP); while B/C ratio <1 indicates that soybean-maize intercropping is not profitable.

Results and discussion

Soil chemical properties

The experimental site was located in a E type of agro-climate zone with three consecutive wet months (rainfall > 200 mm/month) and at least five consecutive dry months (rainfall <100 mm/month) per year (Oldeman, 1975). The soil chemical properties of the site are listed in *Table 1*. Based on the pH value of 8.0, this soil belonged to alkaline. The amounts of C organic, total N, and availability of K were considerably low, however the P_2O_5 content was high. The Ca content was considerably high, which is in agreement with normal property of alkaline soil. The Mg and Zn contents were also high as well as the cation exchange capacity (CEC), which was >25 $cmol^+/kg$, while the Zn content was moderate and SO_4, Fe and Mn were present in low concentrations. Under

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tropical climate, neutral soil reaction with a pH ranged from 6.0-7.0, moderate to high N, P_2O_5, K, Ca, and Mg contents are favourable conditions for soybean cultivation (Sumarno and Mansuri, 2013). Hence, the soil chemical properties of the site were less favorable for soybean growth. The CEC, ratios of Ca/Mg, Ca/K, and Mg/K of this soil were also too high for optimal soybean growth. Fageria et al. (2013) revealed that soil with a pH of 6.0, Ca of 1.6 cmol/kg, Mg of 0.9 cmol/kg, CEC of 4.8 cmol/kg, Ca/Mg ratio of 1.9, Ca /K ratio of 5.6, and Mg/K ratio of 3.0 are suitable for soybean growth with 90% maximum yield. The application of N, P, and K fertilizers as described in the materials and methods expectedly would improve the soil fertility regarding increase the maize and soybean productivity.

Table 1. *Chemical properties of Alfisol soil collected from Tuban Regency*

Elements	Value	Status[1)]	Soybean requirement[2)]	Optimal value[3)]
pH H_2O	8.00	Moderately alkaline	6.0-6.8	6.0-7.0
C organic (%)	1.48	Low	Moderate-high	2.0-5.0
N (%)	0.09	Low	Moderate-high	0.21-0.50
P_2O_5 (ppm)	44.70	Very high	Moderate-high	11-15
K ($cmol^+$/kg)	0.15	Low	Moderate-high	0.4-0.5
Ca ($cmol^+$/kg)	12.43	High	Moderate	6-10
Mg ($cmol^+$/kg)	3.19	High	Moderate	1.1-2.0
CEC ($cmol^+$/kg)	25.10	High		17-24
SO_4(ppm)	9.34	Very low		100
Mn (ppm)	2.49	Moderate		4.5
Fe (ppm)	0.35	Very low		2.5-4.5
Zn (ppm)	1.08	Plenty available		0.5-1.0

[1)] Indonesian Soil Research Institute (2009), [2)] Sumarno and Mansuri (2013), [3)] Indonesian Soil Research Institute (2019)

Rainfall

The rainfall data (*Table 2*) shows that the first and second month for S+M 0 DASP, S+M 10 DASP, and S+M 20 DASP treatments were categorized as wet month with at least 200 mm rainfall/month, except for the second month of treatment S+20 DASP with 119 mm/month rainfall only. All these amounts were sufficient to meet the water requirement for both maize and soybean growth. During the third month, the three intercropping treatments experienced drought as there was merely one rainy day with 40 mm of rainfall at 80 DASP. The absence of rainfall after 80 DASP until harvesting time considerably exposed the maize crop to moisture stress at the final generative growth stage, particularly for maize grown at 10 and 20 days after soybean planting, resulting in poor maize yields.

The amount of rainfall seen in the three intercropping treatments of S+0 DASP, S+10 DASP, and S+20 DASP was 621 mm, which was supposed to be enough for soybean plants that needs 450-500 mm of water during the growing period (Schmidt, 2018). On the other hand, different amounts of rainfall were received by the maize plants due to different planting times c.a. 621 mm, 590 mm, and 424 mm for S+M 0 DASP, S+M 10 DASP, and S+M 20 DASP, respectively (*Figure 4 and Table 2*). All these amounts were higher than the total water requirement (312 mm) for maize grown under dry climate condition in Indonesia (Haruna et al., 2022). About 55.4% of the total water was required for generative growth starting from reproductive phase up to kernel development.

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Meanwhile, maize plants needed 117.4 mm, 146.7 mm, and 26 mm for vegetative growth, reproductive and kernel development, respectively (Haruna et al., 2022). Despite enourmous water available from rainfall in the present study, the rain merely occurred during the vegetative phase of maize, especially for maize planted at 10 and 20 days after soybean. However, there was only 40 mm of rainfall available during the entire generative growth phase. This suggests that maize plants obviously suffered from drought stress, especially during the seed filling process. In particular, Dena 1 and Dega 1 varieties, which normally have maturity of 78 and 73 DAP, both crops experienced early drought condition during the final generative phase as the last rain occurred at 60 DASP and the crops were then harvested two and seven days before the next rain at 80 DASP. Meanwhile, Argomulyo variety obtained 40 mm of rainfall at 80 DASP before the crop was harvested at 84 DASP. Thus, Argomulyo variety did not suffer from a long drought stress and the process of seed filling occurred normally until the physiological maturity had been reached.

Table 2. *Amount of monthly rainfall and number of rainy days for maize grown under three intercropping treatments in the Alfisol dry land of Tuban Regency*

Time	S+M 0 DASP			S+M 10 DASP			S+M 20 DASP		
	Rainfall (mm)	Class*	Rainy days	Rainfall (mm)	Class	Rainy days	Rainfall (mm)	Class	Rainy days
Month 1	206	WM	13	311	WM	13	265	WM	10
Month 2	375	WM	7	239	WM	5	119	MM	3
Month 3	40	DM	1	40	DM	1	40	DM	1
Month 4	-	-	-	-	-	-	-	-	-
Total amount	621		21	590		19	424		14

WM = wet month (> 200 mm/month), MM = moistened month (100-200 mm/month), DM = dry month (<100 mm/month), *) Oldeman (1975) classification

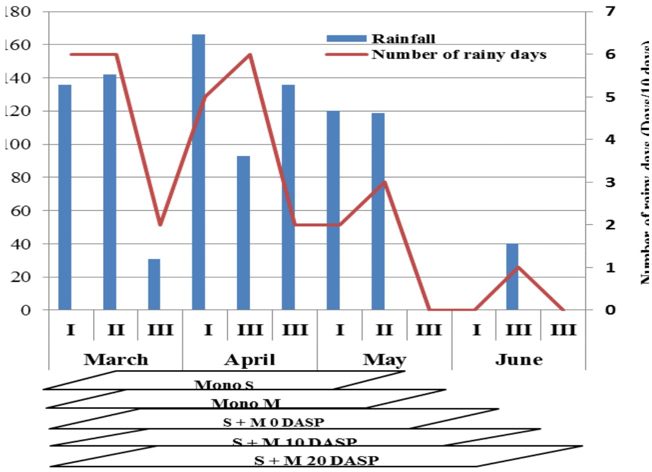

Figure 4. *Distribution of rainfall and number of rainy day during maize and soybean cultivation in the Alfisol dry land of Tuban Regency. M: Maize, S: Soybean, Mono M: maize monoculture, Mono S: soybean monoculture, S+M 0 DASP: soybean intercropped with maize planted at the same day as soybean, S+M 10 DASP: soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP: soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting*

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Light intensity

The maize crops significantly decreased the light intensity received by soybean canopy both measured at 40 and 60 DASP. Such phenomenon was observed for the three soybean varieties (*Table 3*). The lowest light intensity received by soybean canopy was seen in the intercropping treatments of S+M 0 DASP and S+M 10 DASP. Conversely, full sunlight was received by soybean monoculture (*Table 3*).

Table 3. *Light intensity above the soybean canopy of soybean monoculture and intercropped with maize in the Alfisol dry land of Tuban Regency*

Cropping pattern	**Light intensity above the soybean canopy at 40 DASP (%)**			**Light intensity above the soybean canopy at 60 DASP (%)**		
	Argomulyo	**Dena 1**	**Dega 1**	**Argomulyo**	**Dena 1**	**Dega 1**
Mono S	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a	100.00 a
S+M 0 DASP	41.95 e	45.18 e	44.27 e	65.18 cd	59.39 cde	51.15 def
S+M 10 DASP	41.19 e	38.70 e	38.42 e	43.05 ef	40.17 f	42.82 ef
S+M 20 DASP	82.28 b	67.10 c	56.63 d	83.64 ab	73.13 bc	67.32 cd

Figures followed by the same letters are not significantly different (P> 0.05) for each observation at 40 and 60 DASP (days after soybean planting); Mono S= Soybean monoculture, S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting

Table 3 also exhibits that the later the maize grown, the greater the light intensity above the soybean canopy recorded. However, at 40 DASP, the light intensity above the canopy of three soybean varieties was similar for S+M 0 DASP and S+M 10 DASP treatments, while it significantly increased for S+M 20 DASP treatment. This suggests that the smaller the light intensity above the soybean canopy, the greater was the shade level caused by the maize plants. The similar trend of light intensity was also noted at 60 DASP (*Table 3*). The light intensity ranged from 38.42-82.28% and 40.17-83.64% or equivalent to a shade level of 17.72-61.56% and 16.36-59.83% at 40 DASP and 60 DASP, respectively. Low shade level or high light intensity was particularly observed in S+M 20 DASP treatment due to poor growth of maize associated with low rainfall amounts during the vegetative growth period (*Table 2 and Figure 4*).

In terms of variety, the greatest light intensity was observed above the canopy of Argomulyo variety, followed by light intensity above Dena 1 and Dega 1 canopies, reflecting the differences in genetic tolerance toward shade. Dena 1 is specifically released as a shade tolerant variety up to 50% (Balitkabi, 2016). The maize shade may cause phenotypic changes on the soybean plant, such as elongation of the stem and petioles (etiolation), lower number of branches, and greater specific leaf area as self-defense mechanisms toward shading stress (Wen et al., 2020). Such changes, particularly etiolation likely occurred in this study. An intercropping maize and soybean study in China using a double row with an alley for maize as performed in this study, showed a better result than the double row intercropping alone as the photosynthetic active radiation (PAR) above the soybean canopy increased by 1.42-1.93-fold (Liu et al., 2018). Thus, this intercropping model was effective in decreasing the shade effect of maize and increasing the efficiency use of solar radiation and rate of photosynthesis (Liu et al., 2017).

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Yield and yield components

Grain yields of maize and soybean

Intercropping of soybean and maize produced significantly lower yields relative to each crop's yield obtained from monoculture. *Table 4* shows that soybean and maize yield reduced by 21.22-48.88% and 26.37-100%, respectively, when both crops were intercropped. On the other hand, Sundari et al. (2019) reported a higher yield reduction in soybean (61.53%) relative to that of maize (31.05%) when both crops were intercropped. This may be due to different planting time as maize was planted earlier than soybean. Lower yield of each crop in mix cropping than that in sole cropping was also experienced in barley (*Hordeum vulgare* L.) and faba bean (*Vicia faba L.)* (Agegnehu et al., 2006) as well as in maize and soybean (Hafid et al., 2021).

Table 4. *Yields of maize and soybean grown under monoculture and intercropping and yield reduction of each crop in relation to intercropping performed in Tuban Regency*

Cropping pattern	Maize		Soybean	
	Seed yield (t/ha)	**Yield reduction (%)**	**Seed yield (t/ha)**	**Yield reduction (%)**
Monoculture:	5.65 a	0.00	2.45 b (Argomulyo)	0.00
			3.13 a (Dena 1)	0.00
			2.45 b (Dega 1)	0.00
Intercropping:				
Maize 0 DASP + Argomulyo	3.66 c	35.22	1.70 ef	30.61
Maize 0 DASP + Dena1	4.16 b	26.37	1.86 cd	40.58
Maize 0 DASP + Dega1	3.36 c	40.53	1.67 ef	31.84
Maize 10 DASP + Argomulyo	1.42 e	74.87	1.60 fg	34.69
Maize 10 DASP + Dena1	1.75 d	69.03	1.77 de	43.45
Maize 10 DASP + Dega1	1.66 de	70.62	1.93 c	21.22
Maize 20 DASP + Argomulyo	0.00 f	100.00	1.53 g	37.55
Maize 20 DASP + Dena1	0.00 f	100.00	1.60 fg	48.88
Maize 20 DASP + Dega1	0.00 f	100.00	1.90 c	22.45

S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting

The current study showed a greater reduction in maize yield associated with its planting time in soybean and maize intercropping pattern. On average, a yield reduction of 34.04% was noted when maize was planted at the same date as soybean. Planting maize 10 days later resulted in higher yield reduction i.e., 71.50% and no grain yield was obtained when maize was planted 20 days after soybean (*Table 4*). The most reason for this result was unavailable sufficient water for maize growth, particularly during the generative growth phase as previously discussed. Meanwhile, a yield of 5.65 t/ha of maize was obtained from monoculture treatment. This yield was slightly higher than the average of national maize productivity in Indonesia that was about 5.23 t/ha (Hudoyo and Nurmayasari, 2019).

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The soybean yield reduction for Argomulyo, Dena 1, and Dega 1 variety was 34.29%, 26.60%, and 26.08%, respectively, compared to their yields in monoculture. In other words, the yields of Argomulyo, Dena 1, and Dega 1 in intercropping were around 65.71%, 73.40%, and 73.92% of their yields in monoculture (*Table 4*). A relatively higher reduction of soybean yield in intercropping pattern relative to that in monoculture was reported by Liu et al. (2017) and Liu et al. (2018), *c.a.* 32.5% and 47%, respectively. Yang et al. (2015) also recorded a higher yield of soybean monoculture relative to its intercropping with maize (1.96 t/ha *vs* 1.06 t/ha) with 45.9% yield reduction. It is obvious that intercropping may cause shading stress toward soybean as a shorter plant, thus it limits the vegetative growth due to a smaller leaf size and less number of branches (Liu et al., 2017). This subsequently would decrease the photosynthetic rate, carbohydrate production, biomass accumulation and distribution, and yield (Liu et al., 2017; Hussain et al., 2019).

Dega 1 variety showed the highest yields for both monoculture and intercropping, followed by Dena 1 and Argomulyo (*Table 4*), suggesting different cultivar tolerance grown under this study condition. The superiority of Dega 1 was also reported by Anggraeni et al. (2020), where the seed yield of Dega 1 variety was slightly higher (11.1%) than that of Argomulyo variety grown under maize and soybean intercropping. This higher seed yield was mainly because of higher seed size of Dega 1 (22.55 g/100 seeds) than that of Argomulyo (17.06 g/100 seeds) (Balitkabi, 2016) despite the similar number of filled pods and branches per plant.

The seed yields of Dena 1, and Dega 1 varieties grown as monoculture in the present study (*Table 4*) were lower than the yield potential listed in the variety description *c.a.* 2.9 t/ha and 3.82 t/ha, respectively (Balitkabi, 2016). However, the seed yield of Argomulyo variety was slightly higher than its recorded average yields (1.5-2.0 t/ha) (Balitkabi, 2016). Lower seed yields seen in this study were due to less rainfall availability for the soybean growth, while those figures of yield potential recorded in the variety description are normally obtained under optimal conditions. In this study, high amount of calcium was also presence in the Alfisol soil as listed in *Table 1*, resulting in a low availability of P for the plants and poor efficiency of P fertilizer. P has an important role in cellular energy transfer, respiration, and photosynthesis. Deficiency of P may cause plant stunting with shortened internodes and poor root systems (Hopkins and Ellsworth, 2005). This condition would considerably affect the plant growth and development and ultimately the seed yield.

Filled pod number and 100-seed weight

There was an interactive effect of intercropping treatments on the number of filled pods of soybean varieties, indicating that the response of a particular soybean variety was specific to particular intercropping pattern. The highest number of filled pods (35 pods) was obtained by the monoculture of Dena 1 variety, while the lowest number (24.33 pods) was seen for Dega 1 variety intercropped with maize (S+M 10 DASP) as presented in *Table 5*.

Argomulyo variety responded positively to intercropping treatment through a significant increase of filled pod number per plant from monoculture (27 pods) to three intercropping treatments that ranged from 29.3-33.6 pods. On the other hand, Dena 1 variety had the highest number of filled pods (35 pods) under monoculture and the plants yet retained high number of filled pods when it was intercropped with maize either maize was grown at the same day as soybean or 10 days later. However, the number of filled

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pods significantly reduced when maize was grown 20 days later. The high number of filled pods produced by Dena 1 variety either grown as monoculture (Harsono et al., 2020; Hafid et al., 2021) or intercropped with maize was also recorded by Kristiono and Muzaiyanah (2021). However, some studies revealed that the number of filled pods in monoculture was higher than that of in intercropping (Harsono et al., 2020; Wang et al., 2020; Wu et al., 2021). Meanwhile, a study conducted by Gutu et al. (2015) showed a greater filled pods number under intercropping than that of sole cropping. Differences in soybean cultivar, planting season and time as well as growth environment conditions may contribute to such results.

Table 5. *Filled pod number per plant and 100-seed weight of soybean monoculture and intercropped with maize in the Alfisol dry land of Tuban Regency*

Cropping pattern	Variety	Number of filled pod/plant	100-seed weight (g)
Mono	Argomulyo	27.00 cd	11.33 h
	Dena 1	35.00 a	13.14 de
	Dega 1	29.33 bcd	18.42 a
S+M 0 DASP	Argomulyo	30.67 abc	12.22 g
	Dena 1	29.67 abcd	13.41 cd
	Dega 1	29.00 bcd	17.77 b
S+M 10 DASP	Argomulyo	29.33 bcd	12.81 ef
	Dena 1	32.00 abc	13.21 de
	Dega 1	24.33 d	18.56 a
S+M 20 DASP	Argomulyo	33.66 ab	12.48 fg
	Dena 1	27.33 cd	13.96 c
	Dega 1	25.00 cd	17.35 b
	Dena 1	32.00 abc	13.21 de

Figures within a coloum followed by the same letters are not significantly different (P> 0.05) Mono = soybean monoculture, S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting

Dega 1 variety gave the lowest amount of filled pods among the three varieties in all intercropping patterns studied. Also, Dega 1 had similar number of filled pods either grown as monoculture or intercropping. This suggests that the capacity of this variety in setting the filled pods was not consistently influenced by a particular cropping pattern. The different numbers of filled pods among the three studied varieties might be caused by the different length or duration of plant development growth as previously revealed by Wang et al. (2020). This statement is supported by the different maturity dates of Argomulyo, Dena 1, and Dega 1 *c.a.* 80-82, 78, and 69-73 days, respectively (Balitkabi, 2016). Arshad et al. (2006) and Sulistyo et al. (2018) reported a positive correlation between the number of filled pods with yield (r =0.67 and 0.37, respectively). However, no significant correlation was obtained for both characteristics in this study (data not shown). In addition to filled pod number, yield is also dictated by the plant height, number of branches, and weight of accumulated dry matter in the seeds (Arshad et al., 2006; Sulistyo et al., 2018).

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The cropping pattern of maize and soybean variety significantly affected soybean seed size which was shown by the 100-seed weight (*Table 5*). Dega 1 variety consistently gave the largest seed size when grown either as monoculture or intercropped with maize, followed by Dena 1, and Argomulyo which had the smallest seed size. The 100-seed weight of each soybean variety was only slightly different, even similar under such four cropping patterns, suggesting that differences in this characteristic are predominantly related to cultivar or variety. This reflects that soybean can be intercropped with maize without giving much effect on the seed size. Liu et al. (2017) also observed that intercropping soybean with maize may reduce the biomass and number of grain or grain yield; however, the grain size remained the same. Similar finding was recorded by Wen et al. (2020) who found no significant effect on the weight of soybean seed, even though the plant dry weight declined with increasing shading. Soybeans grouped as a large-seeded if the 100-seed weight is >14 g and 10-14 g for medium-seeded (Badan Benih Nasional, 2013). Large-seeded soybean is particularly desirable for ingredient of tempe as it positively correlated with tempe yield and appearance acceptability (Ginting et al., 2009). This is essential as about 50% of soybean available for consumption in Indonesia is utilized for tempe, while small, medium, and large-seeded soybeans are suitable for tofu which constitutes about 37% (Data and Information Centre of Agriculture, 2016).

The results obtained in this study were slightly lower than that of 100-seed weight described in the variety description for Dega 1 (22.98 g), Dena 1 (14.3 g), and Argomulyo (16.0 g), respectively (Balitkabi, 2016). Growing conditions, particularly the dry land with high pH (*Table 1*) and drought stress (*Figure 4*) conditions during reproductive stage may contribute to this finding as smaller seed sizes are normally obtained under such less optimal conditions (Parveen et al., 2016). Ginting et al. (2021) also revealed that soybeans grown in the acid soil showed smaller values of 100-seed weight as well as under water stress condition (Maleki et al., 2013) associated with lower dry matter accumulation in the seeds and high number of under developed seeds (Wijewardana et al., 2019).

Reducing light intensity above the soybean canopy in all three intercropping treatments resulted in shading stress as a result of reduction of light received by soybean leaves gave a consequence of shading stress intensity (SI) by 25.82%, 24.82%, and 28.65%. This level of stress resulted in soybean yield reduction by 18.13%, 27.41%, and 31.42% for treatment S+M 0 DASP, S+M 10 DASP, and S+M 20 DASP, respectively (*Table 5*). These stress intensities were fairly low as Sundari et al. (2019) reported the soybean SI of 61.8% when maize was planted two weeks before soybean in the intercropping pattern. *Table 4* points out the low soybean yield reduction under all intercropping treatments, therefore it is interesting to further investigate the competitive characters of each crop in each intercropping pattern performed in the present study.

Land-use efficiency and competitive ability

Land equivalent ratio (LER)

The technical feasibility or productivity of intercropping soybean and maize was evaluated using a partial and total LER. Total LER is equal to 1.0 indicates that there is no difference in total production both in intercropping and sole cropping. However, if the total LER is greater than 1.0, the intercropping is beneficial as it gives higher production compared to monoculture and it would be unbeneficial if the LER value is less than 1.0 (Egbe et al., 2010; Matusso et al., 2013).

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Table 6 illustrates that intercropping maize and soybean when these two crops were grown at the same time (S+M 0 DASP) gave the highest total LER values ranging from 1.27 to 1.61. Meanwhile, the intercropping patterns of S+M 10 DASP resulted in lower LER values from 0.91 to 1.14, and the LERs even lower (0.63-0.77) at intercropping pattern of S+M 20 DASP. Inserting soybean variety of Dena 1 into the main crop of maize in the cropping pattern of S+M 0 DASP obtained the highest value of LER due to highest yields of both maize and soybean, followed by Argomulyo and Dega 1 varieties with lower LERs. Harsono et al. (2020) reported the dominance of Dena 1 over Argomulyo and Dega 1 varieties in terms of total LER when soybean was planted at the same time as maize.

Table 6. *Land equivalent ratio (LER) of soybean and maize monocultures and soybean intercropped with maize in the Alfisol dry land of Tuban Regency*

Cropping pattern/ Soybean variety	**Seeds yield (t/ha)**				**Percentage of total yield to maize monoculture (%)**	**LER maize**	**LER soybean**	**Total LER**
	Maize	**Soybean**	**Soybean yield equivalent to maize yield [a)]**	**Total yield**				
Maize monoculture	5.65	-	-	5.65	100	1.00	0.00	1.00
Argomulyo monoculture	-	2.45	3.98	3.98	70	0.00	1.00	1.00
Dena 1 monoculture	-	2.13	3.46	3.46	61	0.00	1.00	1.00
Dega 1 monoculture	-	2.48	4.03	4.03	71	0.00	1.00	1.00
Argomulyo +maize 0 DASP	3.66	1.70	2.76	6.42	114	0.65	0.69	1.34
Dena 1+ maize 0 DASP	4.16	1.86	3.03	7.18	127	0.74	0.88	1.61
Dega 1+ maize 0 DASP	3.36	1.67	2.71	6.07	108	0.60	0.67	1.27
Argomulyo +maize 10 DASP	1.42	1.60	2.60	4.02	71	0.25	0.65	0.91
Dena 1+ maize 10 DASP	1.75	1.77	2.87	4.62	82	0.31	0.83	1.14
Dega 1+ maize 10 DASP	1.66	1.93	3.14	4.80	85	0.29	0.78	1.07
Dena 1+ maize 20 DASP	0.00	1.60	2.60	2.60	46	0.00	0.75	0.75
Argomulyo +Maize 20 DASP	0.00	1.53	2.49	2.49	44	0.00	0.63	0.63
Dega 1+ maize 20 DASP	0.00	1.90	3.09	3.09	55	0.00	0.77	0.77

DASP: days after soybean planting.
Population of 100% maize and soybean crops was 62,500 plants and 333,333 plants/ha, respectively.
[a)] Calculated based on maize selling price of IDR 4,000/kg dried seeds and soybean selling price of IDR 6,500/kg of dried seeds

Total LER values ranging from 1.27 to 1.61 obtained in this study suggests that about 27–61% more land is needed for the monoculture to produce yield equal to that of the intercropping pattern S+M 0 DASP. Therefore, it is more beneficial to practice the maize

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and soybean intercropping with LER >1 rather than their respective monoculture. This result was in accordance to the previous studies reported by Solanki et al. (2011), Matusso et al. (2013), Lv et al. (2014), Tsujimoto et al. (2015), Yang et al. (2015), and Kristiono et al. (2020). Technically, the intercropping of soybean and maize (S+M 0 DASP) is more efficient and productive in terms of land use. Applying two rows of maize with spacing of 200 cm x (40 x 20) cm was the most suitable for maize and soybean intercropping as reported by Sari et al. (2020) that two to three rows of maize gave significantly higher LER compared to that LER obtained from maize and soybean intercropping with one row of maize. Zhang et al. (2015) reported that intercropping of four rows of maize and six rows of soybean gave the highest total LER *c.a.* 1.30 compared to two or six rows of maize and six rows of soybean.

Total LER >1 was obtained in barley and faba bean intercropping, where barley as the main crop with full population and faba bean as a component crop in various populations started from 25 to 62.5% of its sole cropping (Agegnehu et al., 2006). LER ranged from 1.22 – 1.28 was obtained in maize and soybean intercropping with three rows of maize and three, four, and six rows of soybean. This study was conducted during the dry season under optimal conditions with fertilization, sufficient water availability during the critical period, and effective protection from weed, pest and disease attacks (Hafid et al., 2021).

The higher yield of intercropping crops compared to monoculture may relate to complementary and efficient use of the resources by both crops (Liu et al., 2006). Yang et al. (2017) and Kamara et al. (2019) reported that the partial LER of maize was higher than that of soybean, indicating that maize contributed more to the total LER of the intercropping than soybean. However, present study showed that the partial LER of soybean was mostly higher than that of maize (*Table 6*). Different planting times of maize after soybean may be attributed to such finding as zero yield of maize was particularly seen in the cropping pattern of S+M 20 DASP.

The partial LER <1 was obtained by maize and three soybean varieties in all treatments. The partial LERs of soybean were higher compared to those of maize (*Table 6*). The data also present the reduction in LER values of both crops and the reduction values in maize was bigger compared to those in soybean. Delaying the maize planting from 0 to 10 days and then 20 days after soybean planting reduced the partial LER of maize to the average LER values from 0.66 to 0.28 and even to 0. The maize planting delay up to 20 days slightly reduced the partial LER of soybean from 0.75 to 0.72. It is interesting therefore to evaluate the competitive ability of maize and soybean in the current intercropping study.

Competitive ability

The current study revealed that relative crowding coefficient (K) of soybean ranged from 1.07-1.30, which was higher compared to those of maize with K values of 0-0.24 (*Table 7*). The K value of soybean >1 was obtained in maize and soybean intercropping with five rows of soybean *vs* two rows of maize. It means that soybean was dominant and more competitive than maize in this intercropping study. The K value >1 for soybean was also obtained by Cui et al. (2017) in soybean and maize intercropping with two rows for soybean and two rows for maize, respectively. The K value <1 for soybean in soybean and maize intercropping was obtained in plant arrangement of 1:1 for soybean and maize row consecutively (Cui et al., 2017), and plant arrangement of 4:6 for four rows of maize and six rows of soybean as reported by Sundari et al. (2019).

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Table 7. *The competitive parameters of maize and soybean in three intercropping treatments in Alfisol soil of Tuban Regency*

Parameter	Maize	Soybean	Intercropping
Stress Intensity (%)			
S+M 0 DASP	34.04	25.82	
S+M 10 DASP	71.50	24.82	
S+M 20 DASP	100	28.65	
Relative Crowding Coefficient (K)			
S+M 0 DASP	0.44	0.65	
S+M 10 DASP	0.09	0.69	
S+M 20 DASP	0.0	0.57	
Aggressivity Value (A)			
S+M 0 DASP	0.76	-0.76	
S+M 10 DASP	-0.34	0.34	
S+M 20 DASP	-1.09	1.09	
Actual Yield Loss (AYL)			
S+M 0 DASP	0.89	0.14	0.76
S+M 10 DASP	-0.18	0.16	-0.34
S+M 20 DASP	-1.0	0.09	-1.09

S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting

The positive value of maize aggressivity (A) was obtained in S+M 0 DASP treatment, however the value turned to negative when maize was planted 10 and 20 days after soybean (*Table 7*). This value explained that when soybean and maize were planted at the same date, the maize plants (C4 plant) were more dominant than the soybean plants (C3 plant) in terms of obtaining the sunlight, soil moisture and nutrients as well as supported by the maize plant characteristics, such as bigger canopy, taller figure, larger root system, higher photosynthetic activity, growth rate and yield. Conversely, a positive A value of soybean was obtained when maize planted 20 days after soybean, suggesting that soybean growth and yield were dominant over the maize plants that suffered from drought stress. Sari et al. (2022) reported a positive A value of soybean and a negative A value of maize in maize and soybean intercropping (grown at the same time) with two rows of maize and four rows of soybean. A positive aggressive value of soybean in the latter study was resulted from its dominant population, which was three times higher than that of maize (Sari et al., 2022).

The actual yield loss (AYL) is one of intercropping indices among several indices, such as LER, RCC, and AV. Banik et al. (2000) concluded that AYL is more appropriate than other indices, especially for per plant yield estimation. In the current study, the AYL of both maize and soybean were positive when both crops were planted at the same time (*Table 7*). This positive value means that intercropping maize and soybean planted at the same date gave a benefit to both crops. Delaying the maize planting time turned its AYL to negative, and *vice versa* for AYL of soybean. The poor growth of maize under intercropping pattern gave a positive impact toward the competitor crops *i.e.* soybean. The AYL of 0.76 obtained in intercropping of soybean and maize with two rows of maize and five rows of soybean showed a benefit impact when both crops were planted at the

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same date. The same intercropping study conducted by Sundari et al. (2019) with four rows of maize and six rows of soybean, where maize was planted two weeks earlier than soybean, gave a AYL intercropping of 0.37 with a negative AYLvalue for soybean and positive value for maize.

Seed quality

Drying seeds to decrease the moisture content is essential for seed certification purpose. A seed moisture content below 10% is needed for longer storability, even though the maximum level required for seed certification is 12% (Kementan, 2016). *Table 8* shows that the moisture contents of seed produced in this study have met such requirement as mostly was around 9%. This reflects that postharvest handling, particularly harvesting and drying have been properly performed. As the germination testing was done directly seven days after harvest, the seed deterioration was not likely occurred (Mbofung, 2012). The germination data (> 91%), which indicates the initial seed physiological quality (*Table 8*), showed that the seeds derived from all varieties and cropping treatments belonged to high quality seeds as normally the acceptable level for commercial purpose is ≥ 80%. In addition, the seed purity levels were also high (> 99%), thus the seeds obtained in this study could be used for seed multiplication or seed production purpose following the seed certification procedure.

Table 8. *Seed quality of soybean monoculture and intercropped with maize in the Alfisol dry land of Tuban Regency*

Cropping pattern	Variety	Moisture content (%)	Purity (%)	Germination (%)
Mono	Argomulyo	9.19 cd	99.9 a	95 abc
	Dena 1	9.09 defg	99.8 a	95 abc
	Dega 1	9.14 cdef	99.7 a	97 a
S+M 0 DASP	Argomulyo	9.38 ab	99.5 a	95 abc
	Dena 1	8.98 g	99.7 a	96 ab
	Dega 1	9.05 efg	99.6 a	96 ab
S+M 10 DASP	Argomulyo	9.01 fg	99.7 a	97 a
	Dena 1	9.10 defg	99.7 a	91 d
	Dega 1	8.72 h	99.7 a	97 a
S+M 20 DASP	Argomulyo	9.15 cde	99.5 a	93 bcd
	Dena 1	9.47 a	99.7 a	93 bcd
	Dega 1	9.25 bc	99.3 a	92 cd

Figures within a coloum followed by the same letters are not significantly different (P> 0.05). Mono = soybean monoculture, S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting

Seed chemical characteristics

The moisture contents of soybean seeds were fairly low with small variations between treatments (*Table 9*), suggesting that moisture content is likely dictated by postharvest handling, particularly drying. These findings have already met the requirement set for moisture content of soybean (maximum 13%) according to the national standard quality (DSN, 1995), which is safe for storage and distribution.

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Table 9. *Chemical composition of soybean seed harvested from soybean monoculture and intercropped with maize in the Alfisol dry land of Tuban Regency*

Cropping pattern	Variety	Moisture (%)	Ash (% dw)	Protein (% dw)	Fat (% dw)
Mono	Argomulyo	8.57 a	5.30 gh	39.87 a	8.64 g
	Dena1	7.81 d	5.36 f	35.89 cd	12.11 e
	Dega1	7.87 d	5.44 e	36.48 c	13.44 a
S+M 0 DASP	Argomulyo	8.54 a	5.33 fg	37.67 b	8.98 g
	Dena1	8.19 c	5.28 h	36.29 cd	12.64 cd
	Dega1	8.17 c	5.67 a	35.20 de	13.07 abc
S+M 10 DASP	Argomulyo	8.62 a	5.63 ab	34.75 e	11.14 f
	Dena1	8.20 c	5.34 fg	35.53 cde	12.76 bcd
	Dega1	8.26 bc	5.61 bc	34.44 e	13.22 ab
S+M 20 DASP	Argomulyo	8.58 a	5.50 d	39.07 a	10.79 f
	Dena1	8.42 ab	5.27 h	35.97 cd	12.28 de
	Dega1	8.43 ab	5.56 c	35.96 cd	12.96 abc

Figures within a coloum followed by the same letters are not significantly different (P> 0.05). Mono = soybean monoculture, S+M 0 DASP= soybean intercropped with maize, where maize was planted at the same day as soybean, S+M 10 DASP= soybean intercropped with maize, where maize was planted 10 days after soybean, S+M 20 DASP= soybean intercropped with maize, where maize was planted 20 days after soybean, DASP: days after soybean planting, dw = dry weight

Soybean is rich in minerals, such as calcium, phosphate, sodium, potassium, iron, zinc, and magnesium (Bellaloui et al., 2011; Gerliani et al., 2019), which are normally measured as total ash content. Cropping pattern and soybean variety showed slightly differences in ash contents, that ranged from 5.27% to 5.67% (dw) as presented in *Table 9*. The highest value was noted in Dega 1 variety for all cropping patterns, while Dena 1had the lowest value. As the location site is the same, such differences in ash contents may be due to genetic factor or variety. The results in this study were slightly higher than those of 20 soybean genotypes grown in the acidic soil that ranged from 4.51 to 5.31% (dw) as reported by Ginting et al. (2021). However, Seo et al. (2012) found a slightly higher of ash contents (5.9-6.0%) in three transgenic soybean lines grown under drought/saline stress. Thus, in addition to cultivar, the growing conditions, such as climate, type and fertility of the soil, and fertilizer application may also contribute to ash content of soybean seed (Elsheikh et al., 2009).

Argomulyo variety consistently showed the highest protein content in different cropping patterns relative to Dena 1 and Dega 1, which gave the same levels of protein (*Table 9*). However, the protein content for each variety was not significantly different for each cropping pattern, except for Argomulyo that seemed to be declined for S+M (0) and S+M (10) treatments. This suggests that both genetic and growing conditions may dictate the protein content of soybean. The protein content of Argomulyo variety was likely to be sensitive when grown at the same time with maize or within a short time after soybean (10 days), while it became normal for longer maize planting time (20 days). This may associate with the levels of maize shade towards the soybean plant, which may cause morphological and physiological changes, resulting in lowering the capacity of photosynthesis and dry matter accumulation (Liu et al., 2017; Wen et al., 2020). Mantino et al. (2019) also investigated that soybean plant with increasing shade position in the alley of soybean intercropped with trees, had lower seed protein content. Meanwhile, such

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effect of intercropping shade was not seen for Dena 1, a shade tolerant variety (up to 50%) released in 2014 (Balitkabi, 2016), giving the same protein contents for both monoculture and intercropping patterns. Wen et al. (2020) suggested using a shade-tolerant cultivar for high-efficiency of intercropping system of soybean.

The seed protein content of Argomulyo variety obtained from monoculture cropping pattern (39.87% dw) was relatively similar to the value listed in its variety description (39.4% dw), which is normally cultivated under optimal condition. However, a slight decrease in protein content was observed in Dena 1 and Dega 1 compared to those contents published in each variety description, *c.a.* 36.7% (dw) and 37.78% (dw), respectively (Balitkabi, 2016). This reflects the differences in alkaline stress responses of the three soybean varieties with respect to protein content as soybean crop normally needs a pH of 6,0 to 6.8 for optimal growth (Jayasumarta, 2015). Mantino et al. (2019) revealed that the soybean protein content showed a negative correlation with soil pH and a positive correlation with the availability of K and P. Meanwhile, a negative correlation between protein content and rainfall was also reported by Kumar et al. (2006), which is in line with a slight drought occurred in present study.

The fat content was significantly different between soybean varieties and cropping patterns. Dega 1 variety showed the highest fat content in all cropping patterns and followed by Dena 1, while Argomulyo had the lowest value (*Table 9*). Argomulyo variety contained significantly lower fat when grown either as a monoculture or intercropped with maize (0 DASP) relative to two other intercropping patterns. Meanwhile, the fat contents obtained from four cropping patterns were relatively similar for each variety of Dena 1 and Dega 1, suggesting the sensitivity differences between soybean varieties toward the cropping patterns associated with the shade tolerance level. Montino et al. (2019) also found no significant fat content in soybean seed derived from different plant positions in the alley-intercropping system. The fat contents negatively correlated with the protein contents (r = -0.75) as presented in *Figure 5*. Ginting et al. (2018) also recorded a negative correlation between protein and fat contents of 20 Indonesian soybean genotypes tolerant to acid soil (r = -0.64).

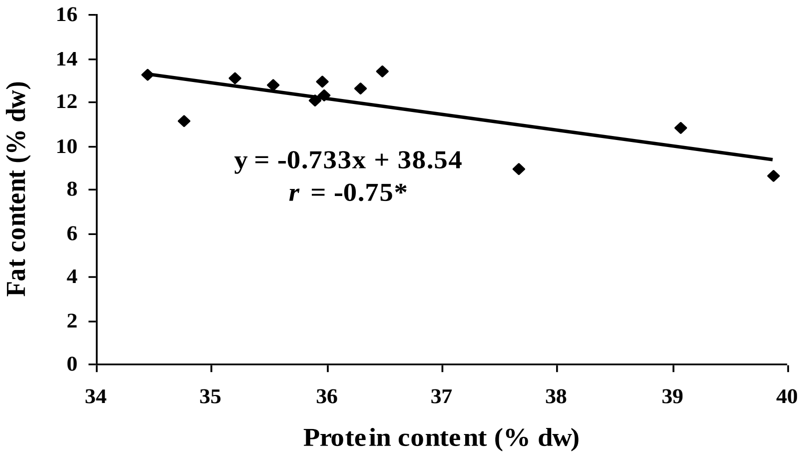

Figure 5. *Relationship between protein and fat contents of soybean seeds grown both as a monoculture and intercropped with maize*

In this study, the fat contents of three soybean varieties either as monoculture or intercropping were much lower than the values described in the variety description, which

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was about 20.8% (dw), 18.8% (dw), and 17.29% (dw) for Argomulyo, Dena 1, and Dega 1, respectively (Balitkabi, 2016). This may relate to alkaline soil condition existed in present study. Under abiotic stresses, generation of reactive oxygen species (ROS) is normally occurred as a result of oxidative stress. They have strong capacities on chemical reactions, thus may damage the photosynthesis components/chlorophyll, lipids, proteins and nucleic acids (Amrijani, 2010; Wen et al., 2020). These physiological changes in soybean plants may lead to undesired qualitative and quantitative changes in the production of fatty acid, a component of triacylglycerol (TGA), which constitutes 96-98% of soybean oil (Nguyen et al., 2016). Ohlrogge and Kuo (1984) investigated that acyl carrier protein (ACP) activity increased a long with the fat synthesis in developing soybean seeds, thus any of growth conditions that lower the protein content may also cause effect in fat content of the seeds. In addition, phosphatidylcholine plays an important role in the fat synthesis as a substrate for such acyl modification to form ACP, followed by production of fatty acid in the ACP and subsequent TAG through the Kennedy pathway (Nguyen et al., 2016). This reflects the essential role of phosphate (P) in the process of fat synthesis in soybean plant, meanwhile P is likely less available in the alkaline (calcareous) soil as previously discussed. Thus, these might have been the plausible reasons for low fat contents obtained in this study as lacking information available regarding the relationship between alkaline soil conditions with fat content of soybean seed produced.

Financial feasibility of soybean and maize intercropping

Table 10 shows that all treatments of soybean intercropped with maize required higher production costs compared to soybean monoculture. Similar finding was also observed for maize monoculture, except for 20 DASP. The intercropping of 20 DASP showed a smaller production cost due to poor growth of the maize plants as discussed previously, thus no cost needed for harvesting and postharvest activities.

Soybean intercropped with maize at 0 DASP was more profitable than those of maize and soybean monocultures and the other intercropping patterns (10 and 20 DASP) with the highest profit calculated for Dena 1 variety due to its highest yield (*Table 10*). Both maize and soybean monocultures as well as soybean intercropped with maize at 0 DASP were economically feasible as referred to their B/C ratios that were greater than 1.0. Intercropping of Dena 1 variety with maize at 0 DASP showed the highest B/C ratio, *c.a.* 1.92, meaning that an expenditure of IDR 1,000 for production cost would give a profit of about IDR 1,920. Meanwhile, the intercropping pattern of 10 DASP and 20 DASP had B/C ratio less than 1.0, thus they were not economically feasible, particularly due to quite low or even zero yield of maize, resulting in small values of farming revenue (*Table 10*).

Even though the production cost of 0 DASP intercropping was greater than either maize or soybean monoculture, it considerably gave greater profit that ranged from IDR 14,397 million to IDR 18,878 million per ha relative to maize monoculture that was approximately IDR 14,331 million per ha (*Table 10*), suggesting that this cropping pattern is promising to be introduced in the maize producing area. In terms of soybean variety, Dena 1 was suitable for intercropping purpose as it showed higher land-use efficiency (*Table 6*) and profit compared to other varieties, thus economically is feasible to be practiced. This result agrees with Seran and Brintha (2010) who revealed that intercropping resulted in a greater land use index, thus gave a higher net return.

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Table 10. *Financial analysis of maize and soybean grown in monoculture and soybean intercropped with maize at different planting times of maize in the Alfisol dry land of Tuban Regency*

Planting methods	Seeds yield (t/ha)		Total revenue (IDR/ha) [a]	Production cost (IDR/ha)		Total cost (IDR/ha)	Total profit (IDR/ha)	B/C ratio
	Maize	Soybean		Maize	Soybean			
Maize monoculture	5,65	0	22,600,000	8,269,000	0	8,269,000	14,331,000	1.73
Argomulyo monoculture	0	2,45	15,925,000	0	7,022,000	7,022,000	8,903,000	1.27
Argomulyo + maize 0 DASP	3,66	1,70	25,690,000	5,984,000	4,540,000	10,524,000	15,166,000	1.44
Argomulyo + maize 10 DASP	1,42	1,60	16,080,000	5,984,000	4,540,000	10,524,000	5,556,000	0.53
Argomulyo + maize 20 DASP	0	1,53	9,945,000	2,992,000	4,540,000	7,532,000	2,413,000	0.32
Dena 1 monoculture	0	2,13	13,845,000	0	6,802,000	6,802,000	7,043,000	1.04
Dena 1 + maize 0 DASP	4,16	1,86	28,730,000	5,452,000	4,400,000	9,852,000	18,878,000	1.92
Dena 1 + maize 10 DASP	1,75	1,77	18,505,000	5,452,000	4,400,000	9,852,000	8,653,000	0.88
Dena 1 + maize 20 DASP	0	1,60	10,400,000	2,726,000	4,400,000	7,126,000	3,274,000	0.46
Dega 1 monoculture	0	2,48	16,120,000	0	6,622,000	6,622,000	9,498,000	1.43
Dega 1 + maize 0 DASP	3,36	1,67	24,295,000	5,718,000	4,180,000	9,898,000	14,397,000	1.45
Dega 1 + maize 10 DASP	1,66	1,93	19,185,000	5,718,000	4,180,000	9,898,000	9,287,000	0.94
Dega 1 + maize 20 DASP	0	1,90	12,350,000	2,859,000	4,180,000	7,039,000	5,311,000	0.75

DASP: days after soybean planting
[a]The selling price of maize and soybean was IDR 4,000/kg and IDR 6,500/kg of dried seeds, respectively

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The results of some previous studies on intercropping of soybean and maize in some areas in Indonesia, including Jambi Province (Burhansyah and Sution, 2021) and dry land with dry climate agro-ecosystem of West Sumbawa Regency in East Nusa Tenggara Province (Rustiana et al., 2021) were in accordance with the finding of this study. Similar studies in some regions outside Indonesia, such as in Lexington, Illinois, USA also found that intercropping of maize and soybean increased both the production and profit (Huffman, 2021). Raza et al. (2020) who did the study in Sichuan Province, China and Punjab Province, Pakistan reported that the intercropping system gave a better option in obtaining high yield of the crops with high net income and high utilization of available resources. Intercropping of maize with other beans, such as French bean, pigeon pea, and cowpea in India also resulted in high value of LER ranging from 1.35-1.51 and provided higher cash in return or profit to small holder farmers compared to maize monocropping (Seran and Brintha, 2010).

Conclusion

The intercropping pattern of soybean with maize, which were planted at the same time showed higher values of total LER, yield, and profit than that of maize or soybean monoculture. Among three soybean varieties, Dena 1 gave the highest total LER (1.61), total yield (7.18 t/ha) and total profit IDR 18,878,000 with a B/C ratio of 1.92. The intercropping of soybean also produced a relatively similar 100-seed weight to that of monoculture. Meanwhile, the protein content was slightly decreased and remarkably decreased for fat content of both cropping patterns in relation to alkaline/calcareous soil condition. The physical and physiological quality of the seeds obtained from either soybean monoculture or intercropping was fairly high and suitable for seed production. These results suggest that intercropping of soybean with maize is promising to be introduced in the maize producing area of Alfisol dry land.

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