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Soybean-maize intercropping feasibility under drought-prone area in East Java, Indonesia

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Abstract. *Harsono A, Elisabeth DAA, Muzaiyanah S, Rianto SA. 2020. Soybean-maize intercropping feasibility under drought-prone area in East Java, Indonesia. Biodiversitas 21: 3744-3754.* The study aimed to determine the land productivity, economic feasibility, and soybean cultivar which is suitable for intercropped with maize in maize production center on dryland-upland in East Java, Indonesia. The study was conducted in Semanding and Merakurak Sub-districts, Tuban District, East Java, Indonesia at the end of rainy season (March-July 2019). The study used a factorial randomized block design with three replications. The first factor was planting patterns, namely: soybean intercropping with maize, maize monoculture, and soybean monoculture. The second factor was soybean cultivars, namely: Argomulyo, Dena 1, and Dega 1. The maize variety used was NK Hybrid 212. The result of study indicated that by intercropping and selecting appropriate cultivar, soybean could be developed on dryland-upland area. Soybean intercropping with plant spacing of 30 cm x 15 cm and two seeds per-hill and maize in double row with plant spacing of (40 x 20) cm x 200 cm and one seed per-hill was able to produce maize seeds yield as high as maize increase LER by 1.69, and increase farming income. Dena 1 intercropping with maize was able to provide higher benefit, economic feasibility, and land-use efficiency than Argomulyo and Dega 1, even though Dega 1 had the strongest competitiveness, and Argomulyo had the higher soybean yield.

Keywords: Dryland-upland, intercropping, maize, soybean

INTRODUCTION

Soybean is the third strategic food commodity after rice and maize in Indonesia. The average of soybean consumption per capita in Indonesia is 9 kg year^{-1} (Riniarsi 2016). Number of population in Indonesia is 260 million (Statistics Indonesia [BPS] 2019). Therefore, the need for soybean is about 2.3 million t year^{-1}. However, Statistics Indonesia [BPS] (2019) recorded that the domestic soybean production in 2017 only reached 538,000 t. The Indonesian government does various efforts to increase domestic soybean production in achieving national self-sufficiency, but soybean harvested area continues to decrease from year to year because it is not able to compete with maize. In the 2014-2017 period, soybean harvested area decreased from 614,000 ha to 355,000 ha, while the maize harvested area increased from 3.8 million ha to 5.5 million ha (Statistics Indonesia [BPS] 2019).

Current national soybean productivity is 1.5 t ha^{-1}. Therefore, based on study of Firdaus (2015), to achieve national soybean self-sufficiency, the soybean productivity should be increased 1.6 t ha^{-1} and requires a harvest area of 1.89 million ha, so an additional harvest area of around 1.5 million ha is still needed. The increase of soybean production through expansion of planting areas can be done on suboptimal lands. One of them is in dryland-upland, which has characteristics of never being flooded, has rainfall < 2,000 mm year^{-1} and has a number of dry months > 7 months (<100 mm month^{-1}). The potential of dryland for food crop development in Indonesia reaches 3.7 million ha, mostly found in Bali and Nusa Tenggara, Sulawesi as well as Java, respectively (Mulyani et al. 2013). However, the insufficient and non-uniform distribution of rainfall on dryland results in frequent drought during the growing period triggering crop stress affected the yields reduction and even crop failure (Yazar and Ali 2017).

Food crop widely planted by farmers in DLDC is maize. Maize is one of major staple food and also a source of income for farmers (Prasanna 2012; Amegnaglo 2018; Kornher 2018). Maize productivity in dryland is relatively low, which ranges from 2.5 to 5.0 t ha^{-1} (Statistics Indonesia [BPS] 2019). Low maize productivity is caused by the erratic distribution of rain and the un-optimum maize cultivation applied by farmers. According to Machado et al. (2008), the optimal productivity of dryland where water availability is limited can be achieved through the application of cropping system that can improve water use efficiency, including intercropping. Liang et al. (2020) reported that during 2016 to 2017, cotton intercropping with mungbean in arid area of Northwest China significantly increased total land output, aboveground dry matter, nitrogen uptake, water use efficiency, nitrogen use efficiency, and economic benefit. Intercropping increases water use efficiency of crops by optimizing the soil moisture environment for crop growth (Yin et al. 2020). Based on 47 studies reported in United Kingdom and 43 studies reported in China, maize intercropping with soybean has the average LER of intercropping of 1.32 ± 0.02, indicating the intercropping has potential for substantial land sparing over sole crops. The average fertilizer N equivalent ratio (FNER) was 1.44 ± 0.03, indicating intercrops receive substantially less N fertilizer than sole crops for the same output. These savings of fertilizer are mainly due to the relatively high yield of maize and the lower N input in the intercrop compared to the input in sole maize (Xu et al. 2020).

Introduction of soybean in dryland-upland through intercropping with maize is expected to increase land productivity and farmer's income. Intercropping system has been adopted all over the world due to it can increase radiation use efficiency (RUE) and land-use efficiency (Mahallati et al. 2014; Yang et al. 2015). However, land efficiency ratio (LER) of maize intercropping with soybean rarely reaches 1.4 (Oseni 2010; Lv et al. 2014; Yu et al. 2015), so it often becomes a barrier for the development of maize-soybean intercropping. According to Yu et al. (2015), with good crop arrangement, the LER of maize-soybean relay cropping can reach 1.4-1.8, higher than the LER of intercropping which generally ranges from 1.2 to 1.4.

Soybean intercropping with maize can increase land productivity (Jun-bo et al. 2018; Iqbal et al. 2019). The use of appropriate cultivars and optimal spacing in soybean intercropping is reported to be able to increase land productivity, reduce the risk of crop failure, increase yields of crops and farmer's income (Lithourgidis et al. 2011; Flores-Sanchez et al. 2013; Yang et al. 2015). The distribution of available water and water use efficiency (Rahman et al. 2017), the selection of adaptive varieties and planting pattern (Yang et al. 2015), the spatial arrangement of crops (Belel et al. 2014) as well as competitive ratio, growth improvement and light irradiance (Yang et al. 2014) are critical aspects of intercropping on dryland-upland.

The study aims to determine the land productivity, economic feasibility, and soybean cultivar which is suitable for intercropping with maize in maize production center on dryland-upland.

MATERIALS AND METHODS

Study area

Study on soybean intercropping with maize was carried out on drought-prone area in Gesing Village of Semanding Subdistrict (1 ha) and Temandang Village of Merakurak Subdistrict (1 ha), Tuban District, East Java Province (Figure 1), Indonesia from March to July 2019. The intercropping cultivation followed the existing crop patterns applied by farmers in a year, namely maize-maize or maize-groundnut or maize-mungbean.

Procedures

The study used a factorial randomized block design with three replications. The first factor was planting patterns consisting of soybean intercropping with maize, maize monoculture, and soybean monoculture as presented in Table 1 and Figure 2. The second factor was soybean cultivars or soybean improved varieties consisting of Argomulyo (large-seeded with medium age-80 days for maturity), Dena 1 (shading tolerant seed with 78 days for maturity), and Dega 1 (large-seeded with early mature age-73 days for maturity).

Figure 1. Study sites of Gesing Village of Semanding Subdistrict (-6°57'49", 112°6'24", 36.9 m, 23°) and Temandang Village of Merakurak Subdistrict (-6°52'13", 111°56'14", 51.5 m, 111°), Tuban District, East Java Province, Indonesia

Data analysis

The technical dan economic feasibility of the cultivation technology packages for intercropping and monoculture patterns under the study was analyzed. Data collected included: chemical properties of soil before planting, distribution of rainfall, shade level of maize to soybean, yield of maize and soybean, land equivalent ratio (LER), competitive ratio (CR), and farming income. The soil was analyzed in Soil Laboratory of Indonesian Legumes and Tuber Crops Research Institute (Iletri). The shade level of maize to soybean was observed using a Digital Lux Meter of LX1330B model. The observations were conducted on three plots included on soybean canopy which was not shaded by maize, on soybean crop which was in two rows closest to the double row of maize, and on three rows of soybean crops between two double rows of maize. Each plot was observed in five spots, then the values obtained were averaged.

Land Equivalent Ratio (LER) is calculated by following equation (Liu et al. 2018):

LER: LERm + LERs

Where: LERm: Yim / Ym; LERs: Yis / Ys

LERm and LERs are, respectively, LER value of maize and LER value of soybean partially. Partial LER is not calculated based on the area of land used by each crop but based on the total area of land used in intercropping. Yim and Ym are, respectively, the yield of intercropping and monoculture of maize; while, Yis and Ys are, respectively, the yield of intercropping and monoculture of soybean.

Competitive ratio (CR) is the ratio of LER of each component of the crop in intercropping by calculating the proportion of each crop that has been planted in intercropping since the beginning (Yilmaz et al. 2008). The CR is used as indicator to evaluate the competitive ability of different commodities in intercropping (Uddin et al. 2014; Bi Tra et al. 2016). The CR is calculated by following equation (Uddin et al. 2014):

$$CR = {(Yim/Ym)}/{(Yis/Ys)} \times (Zis/Zim)$$
or
$$CR = (LERm/LERs) \times (Zis/Zim)$$

Where: Zis: proportion of soybean crops in soybean-maize intercropping; Zim: proportion of maize crops in soybean-maize intercropping.

Table 1. The cultivation technology packages were evaluated on dryland-upland in Tuban District, East Java, Indonesia planting season of 2019

Technology inputs	Cultivation technology: Soybean intercropping with maize	Maize monoculture	Soybean monoculture
Land preparation	In Semanding: without land preparation; In Merakurak: good land preparation	In Semanding: without land preparation; In Merakurak: good land preparation	In Semanding: without land preparation; In Merakurak: good land preparation
Drainage channels	Made every 4-5 m; width and depth about 30 cm	Made every 4-5 m; width and depth about 30 cm	Made every 4-5 m; width and depth about 30 cm
Herbicide	Applied 3-5 days before planting soybean and maize	Applied 3-5 days before planting maize	Applied 3-5 days before planting soybean
Planting	Maize: 1 seed per-hill; soybean:2 seeds per-hill	1 seed per-hill	2 seeds per-hill
Cultivars	Maize: NK Hybrid 212 (by Syngenta); Soybean: Argomulyo, Dena 1, and Dega 1	NK Hybrid 212 (by Syngenta)	Argomulyo, Dena 1, dan Dega 1
Planting method	Use manual dibbling tool	Use manual dibbling tool	Use manual dibbling tool
Plant spacing	Maize: double row with spacing of (40 x 20) cm x 200 cm; soybean: 30 cm x 15 cm	80 cm x 20 cm	(30-40) cm x 15 cm
Seed treatment	Agrisoy 200 g per-50 kg of soybean seeds ha^{-1} mixed with wet seeds just before sowing	Not applied	Agrisoy 200 g per-50 kg of seeds ha^{-1} mixed with wet seeds just before sowing
NPK fertilizer	Maize: 300 kg ha^{-1} Urea + 150 kg ha^{-1} SP36 + 50 kg ha^{-1} KCl; soybean: 30 kg ha^{-1} Urea + 60 kg ha^{-1} SP36 + 30 kg ha^{-1} KCl	300 kg ha^{-1} Urea + 150 kg ha^{-1} SP36 + 50 kg ha^{-1} KCl	50 kg ha^{-1} Urea + 100 kg ha^{-1} SP36 + 50 kg ha^{-1} KCl
Organic fertilizer	Maize 1,500 kg ha^{-1}; soybean 600 kg ha^{-1}, applied as seed hill cover	1,500 kg ha^{-1} applied as seed hill cover	1,000 kg ha^{-1} applied as seed hill cover
Pests and diseases control	Sprayed with insecticides	Sprayed with insecticides	Sprayed with insecticides
Harvesting	At physiological maturity stage	At physiological maturity stage	At physiological maturity stage

Notes: NPK fertilizer for maize was applied 5-7 cm on the side of crops with the dosage of 30% N + 100% P_2O_5 + 50% K_2O at 10 days after planting and 70% N + 50% K_2O at 25 days after planting; NPK fertilizer for soybean was applied in a groove about 5-7 cm beside the planting line when the crops were about 10 days after planting

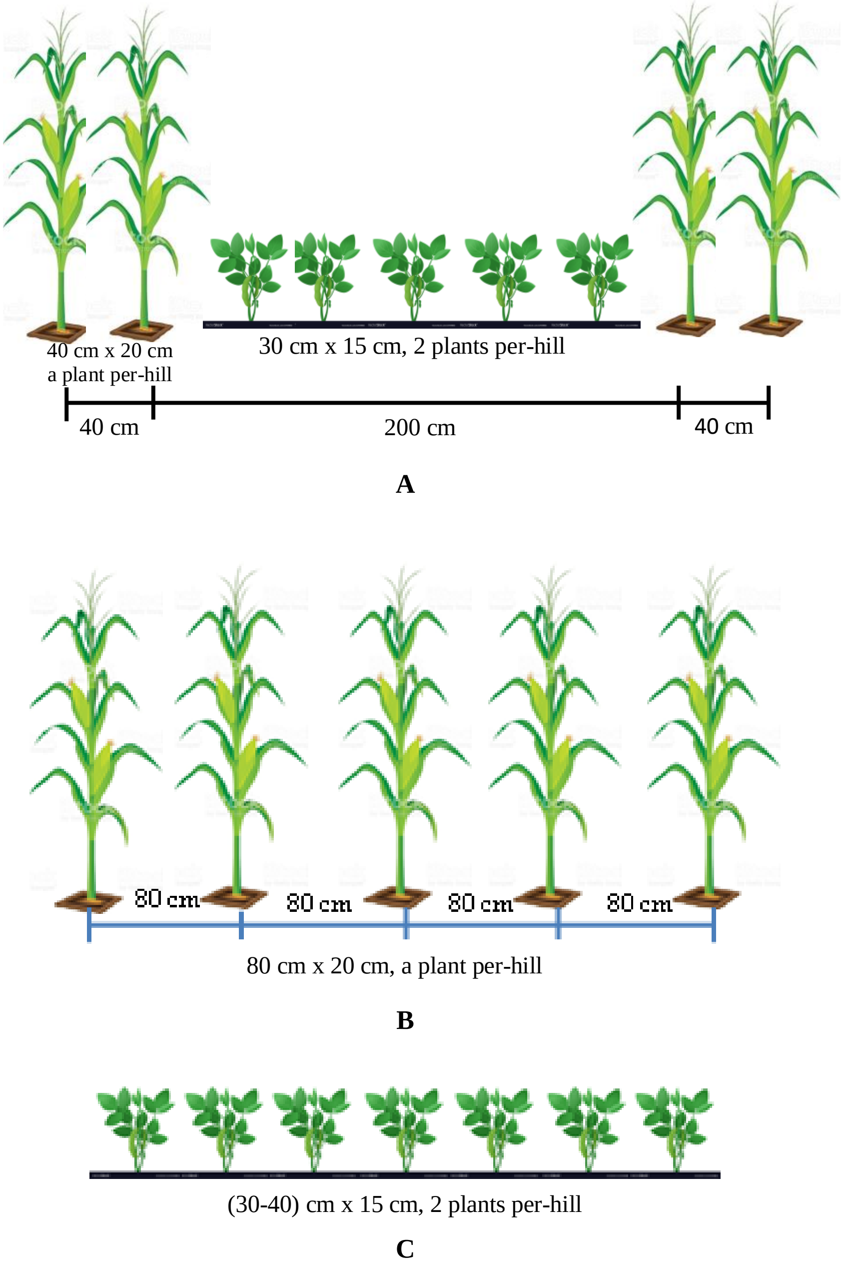

Figure 2. Layout and plant spacing of soybean intercropping with maize (A), maize monoculture (B), and soybean monoculture (C), Tuban District, East Java, Indonesia, planting season of 2019

Economic feasibility of the cultivation technology packages for intercropping and monoculture employs the benefit-cost ratio (B/C ratio) approach with the following equation (Soekartawi 1995 in Istriningsih and Dewi 2015):

$$B/C\ ratio = \frac{(Q \times P) - (VC + FC)}{TVC}$$

Where: B/C ratio: benefit-cost ratio; Q: production (kg ha^{-1} season^{-1}); P: selling price (IDR kg^{-1}); VC: variable cost (IDR) consisting of cost of production materials (seeds, organic and inorganic fertilizers, pesticides, fungicides, etc) and cost of labors; FC: fixed cost (IDR) consisting of depreciation cost of agricultural equipment or machinery; TVC: total cost (IDR ha^{-1} season^{-1}).

B/C ratio is used to measure the feasibility of farming by comparing the total benefit with the total production cost (Habib et al. 2019). The analysis results of B/C ratio are as follows: B/C ratio > 1, soybean-maize intercropping is profitable; B/C ratio = 1, soybean-maize intercropping is at the break-even point; B/C ratio < 1, soybean-maize intercropping is not profitable.

RESULTS AND DISCUSSION

Soil chemical properties

The type of soil in both villages was alfisol which was located on E agro climate zone with a number of wet months was 3-4 months per year. The chemical properties of the soil in the two study sites were classified as alkaline with a pH of 8.3. Organic C and total N contents were very low. P_2O_5 content was very high in Semanding and classified as high in Merakurak. The availability of K in both study sites was rather low. Ca content was very high in accordance with the property of alkaline soil. Mg and Zn content was low to moderate. SO_4 and Mn content were low, Zn is low to moderate, while CEC was classified as moderate (Table 2). The soil with those chemical properties was less suitable for soybean cultivation due to besides being too alkaline the soil was also less fertile. The optimal soil pH for soybean crops is 5.5 to 6.5, with minimal N content and organic matter was classified in moderate category (Abdurachman et al. 2013).

Yield of soybean intercropping with maize

The yields of maize for both intercropping and monoculture in Merakurak were higher than those of Semanding. The yield of maize for intercropping in each study site was not different from the monoculture because the population of maize crops that could be harvested for both intercropping and monoculture were not different (Tables 3 and 9). Soybean monoculture in Semanding and Merakurak could not be developed due to the yields of soybean were only equivalent to 42-72% and 40-42% the yields of maize monoculture. Therefore, the opportunity for developing soybean in Tuban District, particularly in production center of maize is by doing soybean intercropping with maize. Soybean intercropping with plant spacing of 30 cm x 15 cm and two seeds per-hill and maize in double row with plant spacing of (40 x 20) cm x 200 cm and one seed per-hill was able to produce soybean seeds equivalent to 1.3-2.3 t ha^{-1} of maize in Semanding, and 1.9-2.0 t ha^{-1} of maize in Merakurak, depending on the soybean cultivars planted. The intercropping was able to increase maize productivity up to 145% in Semanding and 115% in Merakurak when compared to the monoculture (Table 3). The comparative studies show that in some countries, maize productivity in intercropping is also higher than it in monoculture (Addo-Quaye et al. 2011; Mahmoudi et al. 2013; Matusso et al. 2013).

Land Equivalent Ratio (LER) and Competitive Ratio (CR)

Soybean cultivars planted determine partially the LER value of soybean and maize intercropped. Dena 1 soybean cultivar on intercropping with maize produced the highest partial LER for maize. Conversely, its partial LER for soybean was lower than other soybean cultivars of Argomulyo and Dega 1. In both Semanding and Merakurak villages, the partial LER for soybean from the cultivars of Argomulyo and Dega 1 was consistently higher than Dena 1. The LER of Dena 1 intercropped with maize was higher than the intercropped of Argomulyo and Dega 1 in Semanding and Merakurak. This is due to the CR of maize against Dena 1 was higher than the CR of maize against Argomulyo or Dega 1. On the other hand, the competitiveness of Dena 1 against maize in intercropping was lower than Argomulyo and Dega 1 (Table 4). The LER of maize intercropping in double row of (40 x 20) cm x 200 cm with Dena 1 in Semanding and Merakurak could reach 1.69 and 1.48, respectively. This intercropping model was more efficient and productive than the maize intercropping in double row of (20 x 70) cm x 180 cm in China with the LER 1.4 (Liu et al. 2018). Du et al. (2018) reported that LER soybean intercropping with maize in China is more productive than maize monoculture with LER 1.2 to 1.6, and the yields of maize and soybean were 7.27 t ha^{-1} and 1.00 t ha^{-1}, respectively. Du added that soybean and maize intercropping with double row provides the higher LER compared to the intermittent single row.

Income of soybean intercropping with maize

Soybean intercropping with maize required higher production cost than maize monoculture. However, the intercropping both in Semanding and Merakurak was able to produce higher benefits than maize monoculture (Table 5). In Semanding, maize intercropping with Argomulyo or Dena 1 cultivar was able to produce a benefit of IDR 16.4 million ha^{-1} or IDR 19.1 million ha^{-1}, respectively compared to maize monoculture which only provided a benefit of IDR 13.9 million ha^{-1}. In Merakurak, maize intercropping with Argomulyo or Dena 1 cultivar provided higher benefit than in Semanding, which was IDR 24.9 million ha^{-1} or IDR 25.6 million h^{-1} a, respectively compared to maize monoculture providing a benefit of IDR 24.5 million ha^{-1}. The maize intercropping with Argomulyo or Dena 1 or Dega 1 cultivar was economically feasible due to the B/C ratio was more than 1.0 both in Semanding and Merakurak. The B/C ratio of intercropping was lower than maize monoculture in two study sites. However, the total benefit obtained from intercropping was higher than maize monoculture. Besides, compared to the monoculture, the advantage of intercropping patterns was the lower risk of crop failure, particularly in the areas experiencing high drought stress.

Table 2. Soil chemical properties in two study sites, Tuban District, East Java, Indonesia, planting season of 2019

Elements	Study sites		Adequate values*)
	Semanding	Merakurak	
pH H_20	8.30	8.30	6.6-7.5
Organic C (%)	0.82	1.27	2.01-3.0
N (%)	0.10	0.09	0.21-0.50
P_2O_5 (ppm)	61.1	29.4	11-15
K ($Cmol^+ kg^{-1}$)	0.47	0.38	0.4-0.5
Ca ($Cmol^+ kg^{-1}$)	32.94	19.33	6-10
Mg ($Cmol^+ kg^{-1}$)	0.65	1.86	1.1-2.0
CEC	27.30	18.10	17-24
SO_4	17.90	25.00	100
Mn (ppm)	0.82	0.74	4.5
Zn (ppm)	0.85	0.47	0.5-1.0

Notes: The soil was analyzed in Soil Laboratory of Iletri, Malang, Indonesia. *) The adequate values were according to the criteria of Indonesian Soil Research Institute (ISRI) (2019)

Table 3. Yields of maize and soybean in soybean intercropping with maize, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Seed yield (t ha^{-1})				An increase against maize monoculture (%)
	Maize	Soybean	Soybean equivalent to maize*)	Total yield	
Semanding					
Maize NK 212 monoculture	5.488 b	0	0	5.488	100
Argomulyo monoculture	0	2.430 a	3.949	3.949	72
Dena 1 monoculture	0	1.873 b	3.044	3.044	55
Dega 1 monoculture	0	1.419 c	2.306	2.306	42
Maize NK 212 + Argomulyo	4.876 b	1.447 g	2.351	7.227	132
Maize NK 212 + Dena 1	6.297 b	1.017 cd	1.653	7.950	145
Maize NK 212 + Dega 1	5.635 b	0.820 d	1.333	6.968	127
Merakurak					
Maize NK 212 monoculture	8.877 a	0	0	8.877	100
Argomulyo monoculture	0	2.280 ab	3.705	3.705	42
Dena 1 monoculture	0	2.160 ab	3.510	3.510	40
Dega 1 monoculture	0	2.280 ab	3.705	3.705	42
Maize NK 212 + Argomulyo	7.950 a	1.277 cd	2.075	10.025	113
Maize NK 212 + Dena 1	8.255 a	1.203 cd	1.955	10.210	115
Maize NK 212 + Dega 1	6.317 b	1.273 cd	2.069	8.386	94

Notes: Values in the same column that followed by the same letters show no significant difference at DMRT 5%. Population of maize crops 100% (plant spacing of 80 cm x 20 cm, 2 seeds per-hill) was 62500 crops ha^{-1} and soybean 333,333 crops ha^{-1}. *) Calculated based on maize and soybean selling price were IDR 4000 kg^{-1} and IDR 6500 kg^{-1} of dried seeds, respectively

Table 4. Land Equivalent Ratio (LER) and Competitive Ratio (CR) of soybean intercropping with maize, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	LER of maize	LER of soybean	LER	CR of maize	CR of soybean
Semanding					
Maize NK 212 + Argomulyo	0.89	0.60	1.48	1.32	0.76
Maize NK 212 + Dena 1	1.15	0.54	1.69	1.87	0.53
Maize NK 212 + Dega 1	1.03	0.58	1.60	1.58	0.63
Merakurak					
Maize NK 212 + Argomulyo	0.89	0.56	1.45	1.41	0.71
Maize NK 212 + Dena 1	0.93	0.55	1.48	1.50	0.67
Maize NK 212 + Dega 1	0.71	0.56	1.27	1.23	0.89

Table 5. Farming income of several soybean cultivars intercropping with maize, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Yield (t ha^{-1})		Total revenue (IDR 000 ha^{-1})	Cost production (IDR 000 ha^{-1})		Total cost (IDR 000 ha^{-1})	Total benefit (IDR 000 ha^{-1})	B/C
	Maize	Soybean		Maize	Soybean			
Semanding								
Maize NK 212 monoculture	5.488	0	21,952	8,032	0	8,032	13,920	1.73
Argomulyo monoculture	0	2.430	15,795	0	7,02	7,022	8,773	1.25
Dena 1 monoculture	0	1.873	12,174.5	0	6,802	6,802	5,372.5	0.79
Dega 1 monoculture	0	1.417	9,210.5	0	6,622	6,622	2,588.5	0.39
Maize NK 212 + Argomulyo	4.876	1.447	28,909.5	7,972	4,540	12,512	16,397.5	1.31
Maize NK 212 + Dena 1	6.297	1.017	31,798.5	8,252	4,400	12,652	19,146.5	1.51
Maize NK 212 + Dega 1	5.635	0.820	27,870	8,047	4,180	12,227	15,643	1.28
Merakurak								
Maize NK 212 monoculture	8.877	0	35,508	10,982	0	10,982	24,526	2.23
Argomulyo monoculture	0	2.280	14,820	0	6,962	6,962	7,858	1.13
Dena 1 monoculture	0	2.160	14,040	0	6,762	6,762	7,278	1.08
Dega 1 monoculture	0	2.280	14,820	0	6,962	6,962	7,858	1.13
Maize NK 212 + Argomulyo	7.950	1.277	40,100.5	10,607	4,520	15,127	24,973.5	1.65
Maize NK 212 + Dena 1	8.255	1.203	40,839.5	10,917	4,360	15,277	25,562.5	1.67
Maize NK 212 + Dega 1	6.317	1.273	33,542.5	10,727	4,380	15,107	18,435.5	1.22

Note: Maize and soybean selling prices were IDR 4000 kg^{-1} and IDR 6500 kg^{-1} of dried seeds, respectively

Discussion

The yields of maize and soybean in Merakurak using both intercropping and monoculture patterns were generally higher than in Semanding. It was caused by the higher rainfall in Merakurak compared to Semanding (Figure 3). As stated in the Methodology, this study was carried out at the end of the rainy season following the existing crop pattern of maize-maize. The first maize was planted by farmers at the beginning of the rainy season in December 2018, and the second maize is planted at the end of the rainy season in March 2019 to utilize the remaining rainfall.

In Semanding, the water need for the crops is entirely dependent on rainfall because there are no pumping wells that can be used to irrigate the crops. The rainfall during soybean and maize growth was 477 mm and 482 mm, respectively (Figure 3). The total rainfall met the water need of soybean crops, but it was still lacking for maize. The water need of maize to grow optimally ranges from 539 to 692 mm (Ankidawa and Vanke 2018), and at the peak of reproductive period maize requires water of 549 mm per day (Chuanyan and Zhongren 2007). The distribution of rainfall was also not good. During the vegetative period, the rainfall during the first 30 days reached 285 mm and it was excessive to meet the water needs of soybean and maize. In the first 30 days, soybean only needed water 130 mm. In the reproductive period, the rainfall from 30 to 60 days reached 192 mm, then from 60 days to the harvest time there was no more rainfall (Figure 3). The total rainfall in this reproductive period nearly meets the optimal water need of soybean which is 203 mm (Stansell et al. in Boote et al. 1982).

In Merakurak, the rainfall during the soybean and maize growth was 665 mm and 705 mm, respectively. The rainfall was excessive to meet the water need of soybean, yet enough for maize. Therefore, vegetative period of soybean and maize crops in Merakurak was better than in Semanding as indicated by the differences in plant height and weight (Figure 4, Tables 6 and 7). However, the uneven distribution of rainfall during the plant growth was a constraint in the reproductive period. There was no rain from 60 to 80 days old of soybean and maize crops and they suffered from drought stress; whereas, during that period, both of them needed more water for the seeds filling process. So that the crops did not experience drought stress, at the age of 65 and 75 days they were given the addition of irrigation water from pump wells. There was 40 mm of rain at the age of 80 days, so the crops did not experience drought stress and the process of seeds filling could take place well until the physiological cooking phase of soybean seeds.

The rainfall with higher intensity and better distribution in Merakurak caused the maize crops in Merakurak to grow higher than in Semanding (Figure 4). As a result, the shade level received by soybean crops in Merakurak was higher than the shade received in Semanding (Figure 5). In Semanding, the average shade of maize crops above the canopy of soybean at the age of 40 and 60 days was 43-43% and 55-58%, respectively. Meanwhile, in Merakurak, the average shade of maize crops was 53-59% at the age of 40 days and 58-63% at 60 days (Figure 5). This condition caused the lower competitiveness of soybean crops against maize in Merakurak than in Semanding. As a result, the productivity of soybean with intercropping patterns in Merakurak was lower than in Semanding (Table 3).

In China, intercropping pattern in double row with alley model for maize was better than double row intercropping because it could increase Photosynthetic Active Radiation (PAR) soybean and maize 1.42-1.93 times and 1.02-1.12 times, respectively (Liu et al. 2018). Intercropping with alley model is also able to increase the efficiency of solar radiation use and the rate of soybean crops photosynthesis. The recommended width between maize crops for the best soybean cultivation was 1.6 m-1.8 m and the spacing of maize was in 0.4 m. According to Liu et al. (2017), photosynthesis rate of the upper side of soybean leaves in the intercropping with 1.8 m alley model could reach 80% compared to soybean monoculture. While, in intercropping with single row, the photosynthesis rate of the upper side of soybean leaves only reached 46% compared to soybean monoculture.

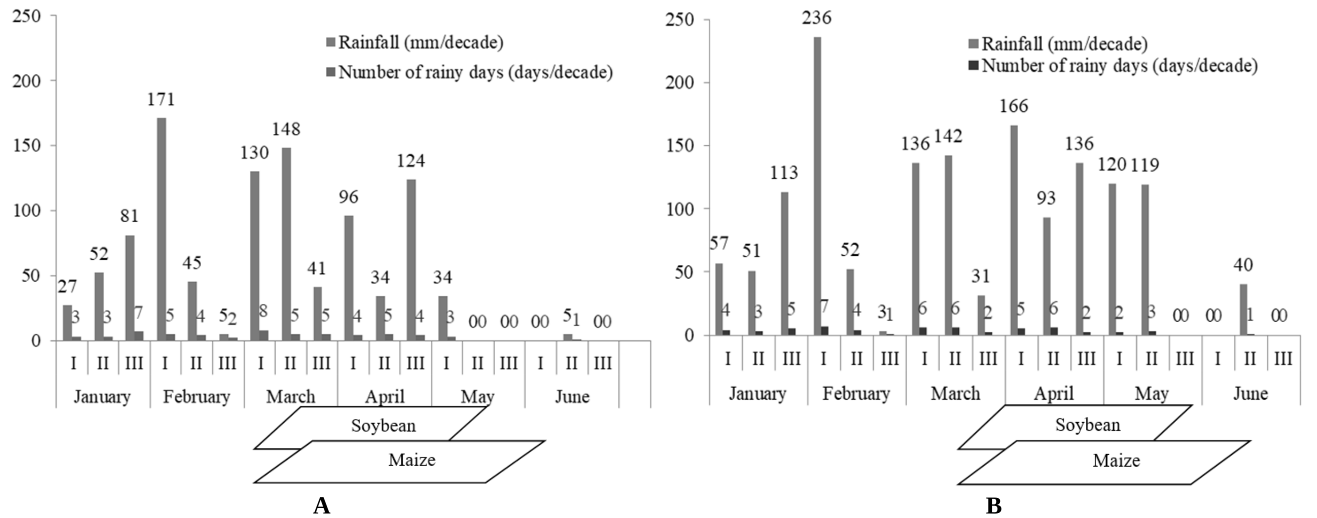

Figure 3. Distribution of rainfall and number of rainy days during crops growth in Semanding (A) and Merakurak (B), Tuban District, East Java, Indonesia, planting season of 2019

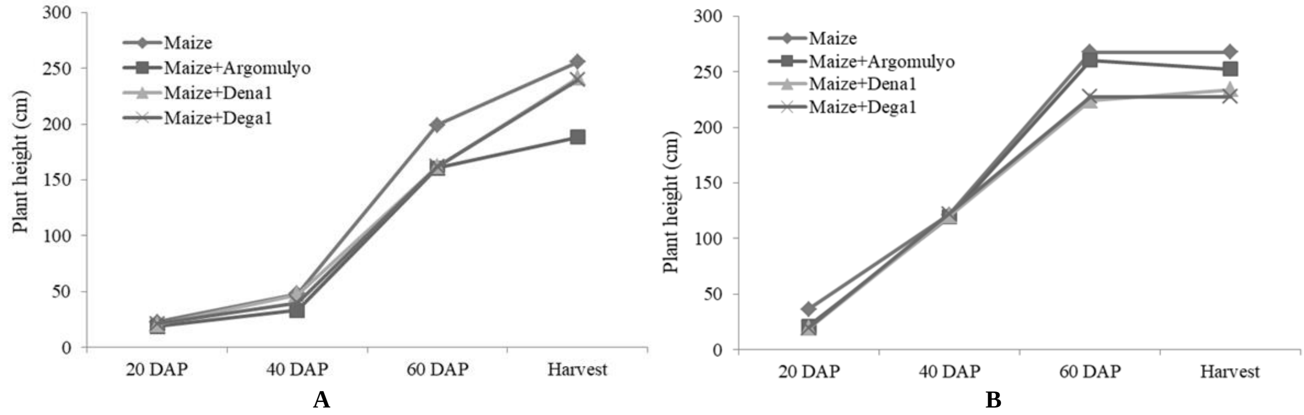

Figure 4. Plant height of maize NK 212 monoculture and intercropping with soybean cultivars of Argomulyo, Dena 1, and Dega 1 in Semanding (A) and Merakurak (B), Tuban District, East Java, Indonesia, planting season of 2019

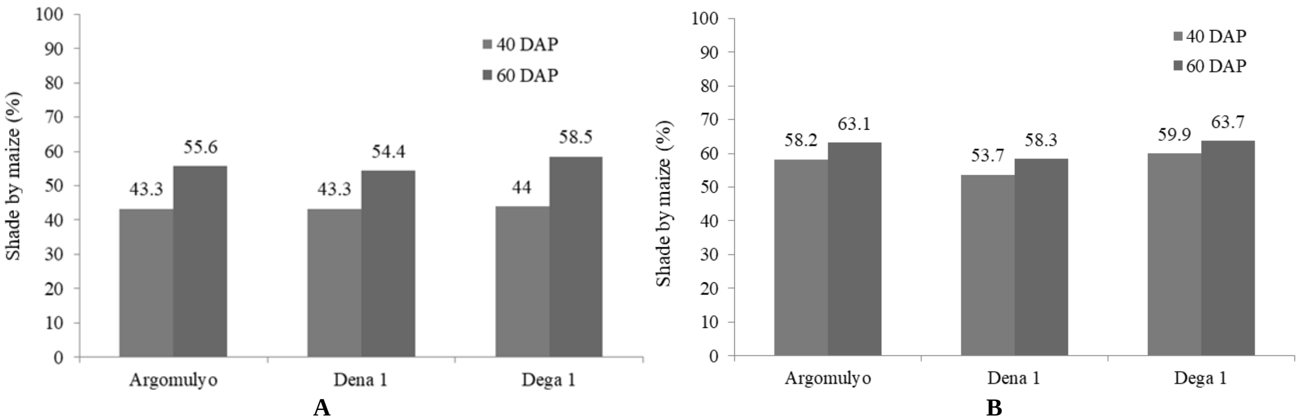

Figure 5. Shade level of maize above soybean canopy at the age of 40 and 60 days in soybean intercropping with maize NK 212 in Semanding (A) and Merakurak (B), Tuban District, East Java, Indonesia, planting season of 2019. Average intensity of solar radiation without shade experienced by soybean at the age of 40 days and 60 days was 138633 lux and 138583 lux, respectively, in Semanding and 149088 lux and 149361 lux, respectively, in Merakurak

Statistically, at the age of 20 and 40 days, plant height of soybean intercropping with maize and soybean monoculture was not significant due to the shade level effect of maize crops above soybean. However, at the harvest time, soybean intercropping grew higher than the monoculture, particularly for Dena 1 (Table 6). In general, soybean monoculture grew better than the intercropping as can be seen from the crop weight of soybean monoculture which is heavier than intercropping (Table 7). In normal conditions, the height of Argomulyo, Dena 1, and Dega 1 cultivars are 40 cm, 59 cm, and 53 cm, respectively (Iletri 2016).

The yields of maize monoculture and intercropping both in Semanding and Merakurak which were not different were caused by the no differences on the number of plants and the number of maize cobs that could be harvested, the number of seeds per each cob and the weight of 100 maize seeds between the two planting patterns (Table 7). Maize intercropping in double row with plant spacing of (40 x 20) cm x 200 cm and one seed per-hill was able to produce the same number of plants and the same number of maize cobs as maize monoculture with spacing of 80 cm x 20 cm and one seed per-hill (Table 8). Liu et al. (2018) reported that the yield of maize intercropping with 1.8 m alley model could reach 90% compared to the yield of maize monoculture. The photosynthesis rate of maize intercropping with alley model was also not significantly different when compared to maize monoculture.

Table 6. Plant height of soybean monoculture and intercropping with maize NK 212 in Semanding and Merakurak, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Plant height (cm)					
	20 DAP		40 DAP		Harvest	
	Monoculture	Intercropping	Monoculture	Intercropping	Monoculture	Intercropping
Semanding						
Argomulyo	16.8 ef	17.9 de	34.9 c	42.1 a	61.3 b	61.2 b
Dena 1	15.7 f	16.6 ef	38.1 abc	41.9 a	64.7 b	69.0 a
Dega 1	14.0 g	16.1 f	38.2 abc	36.0 bc	53.4 c	64.8 b
Merakurak						
Argomulyo	20.1 bc	19.6 bc	40.6 a	39.2 ab	61.0 b	63.0 b
Dena 1	20.8 b	23.0 a	36.2 bc	42.0 a	64.9 b	69.2 a
Dega 1	19.3 cd	19.2 cd	42.0 a	39.8 ab	57.0 c	56.8 c

Notes: DAP = days after planting, Values in the same plant age columns that followed by the same letters show no significant difference at DMRT 5%

Table 7. Crop population and yield components of maize monoculture and intercropping with soybean, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Total dry weight per plant at 60 DAP (g)			
	Maize		Soybean	
	Semanding	Merakurak	Semanding	Merakurak
Maize NK 212 monoculture	83.09 bc	104.66 a	-	-
Argomulyo monoculture	-	-	17.64 ab	15.22 cd
Dena 1 monoculture	-	-	18.52 a	16.86 abc
Dega 1 monoculture	-	-	12.72 e	13.88 de
Maize NK 212 + Argomulyo	80.04 c	103.15 a	16.62 bc	13.87 de
Maize NK 212 + Dena 1	78.26 c	94.03 ab	17.30 ab	12.82 e
Maize NK 212 + Dega 1	75.41 c	74.58	15.17 cd	10.87 f

Note: Values in the same plant (maize or soybean) columns that followed by the same letters show no significant difference at DMRT 5%

The yield of soybean intercropping was lower than soybean monoculture both in Semanding and Merakurak. It was caused by the lower number of soybean crops harvested from the intercropping in both study sites when compared to the monoculture which was 72-74% and 74-76% in Semanding and Merakurak, respectively (Table 9). In general, the number of pods and the weight of 100 seeds between monoculture and intercropping patterns were not different. Thus, it indicated that the three soybean cultivars could grow well in the shade level of 40-60%, with the average solar radiation intensity was in the range of 138,600 lux to 149,300 lux.

The weight of 100 seeds of Dega 1 cultivar was higher than that of Argomulyo and Dena 1. According to Iletri (2016), the weight of 100 seeds of Dega 1, Argomulyo, and Dena 1 cultivars are 22.9 g, 16 g, and 14.3 g, respectively. Even though Dega 1 has heavier weight of 100 seeds, but the lower population could be harvested affected by the yield of Dega 1 that was not different from Argomulyo and Dena 1. Dega 1 is being more susceptible to the drought stress compared to Dena 1 and Argomulyo therefore it causes to the lower population of this cultivar.

Technical and economic feasibility

The LER value of soybean intercropping with maize could reach 1.48-1.69 depending on the soybean cultivars used (Table 4). The higher LER value of Dena 1 intercropping with maize was caused by the lower competitive ratio of Dena 1 against maize (Table 4), so that maize could achieve the optimal yield. This showed that from a technical perspective, the intercropping pattern of soybean with maize was more efficient and more productive in terms of land use than both maize and soybean monoculture. Even though the production cost of the intercropping was higher than both maize and soybean monoculture, but the intercropping was able to provide higher benefits (Table 5). The total benefits of soybean intercropping with maize in Semanding and Merakurak could reach IDR 19.1 million and IDR 25.5 million ha^{-1}, respectively, meanwhile, the total benefits from maize monoculture reached IDR 13.9 million ha^{-1} in Semanding and IDR 24.5 million ha^{-1} in Merakurak. For the purpose to obtain high soybean yield in soybean intercropping with maize, it was better to use Argomulyo cultivar. However, for obtaining higher land-use efficiency and benefit as well as the higher economic feasible intercropping, Dena 1 was more suitable (Tables 3 and 4).

Table 8. Crop population and yield components of maize monoculture and intercropping with soybean, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Harvested plant population (%)*)	Number of harvested maize cobs (x1000)	Number of seeds per-cob	Weight of 100 seeds (g)	Yield (t ha^{-1})
Semanding					
Maize NK 212 monoculture	100.0 a	61.4 a	465.6 ab	28.4 a	5.488 b
Maize NK 212 + Argomulyo	94.3 abc	59.1 a	415.6 ab	29.3 a	4.876 b
Maize NK 212 + Dena 1	88.6 c	57.0 a	382.0 b	28.9 a	6.297 b
Maize NK 212 + Dega 1	80.0 d	47.2 b	399.6 ab	27.6 a	5.635 b
Merakurak					
Maize monoculture	100.0 a	62.7 a	465.3 ab	30.2 a	8.877 a
Maize NK 212 + Argomulyo	95.0 ab	64.9 a	464.0 ab	29.2 a	7.950 a
Maize NK 212 + Dena 1	99.3 a	62.9 a	471.3 ab	31.6 a	8.255 a
Maize NK 212 + Dega 1	90.3 bc	59.6 a	529.7 a	27.9 a	6.317 b

Notes: Values in the same column followed by the same letter show no significant difference in DMRT 5%. *) Population of 100% maize crop with plant spacing of 80 cm x 20 cm, 2 seeds per-hill was 62500 crops ha^{-1}

Table 9. Crop population and yield components of soybean monoculture and intercropping with maize, Tuban District, East Java, Indonesia, planting season of 2019

Planting patterns	Harvested plant population (%)*	Number of pods per plant	Weight of 100 seeds (g)	Yield (t/ha)
Semanding				
Argomulyo monoculture	100.0 a	46.4 ab	13.1 b	2.430 a
Dena 1 monoculture	98.7 a	52.5 a	12.7 bc	1.873 b
Dega 1 monoculture	98.0 a	49.4 a	16.7 a	1.419 c
Maize NK 212 + Argomulyo	73.4 b	39.2 bc	13.4 b	1.447 g
Maize NK 212 + Dena 1	74.1 b	47.3 ab	13.4 b	1.017 cd
Maize NK 212 + Dega 1	72.3 b	46.1 ab	17.3 a	0.820 d
Merakurak				
Argomulyo monoculture	99.2 a	51.4 a	10.7 c	2.280 ab
Dena 1 monoculture	100.0 a	46.0 ab	11.7 bc	2.160 ab
Dega 1 monoculture	95.0 a	40.3 bc	16.7 a	2.280 ab
Maize NK 212 + Argomulyo	74.9 b	32.3 c	11.3 bc	1.277 cd
Maize NK 212 + Dena 1	76.1 b	39.3 bc	11.7 bc	1.203 cd
Maize NK 212 + Dega 1	74.6 b	51.3 a	18.1 a	1.273 cd

Notes: Values in the same column that followed by the same letters show no significant difference at DMRT 5%. *) Population of 100% soybean crops with plant spacing of 40 cm x 15 cm, 2 seeds per-hill was 333,333 crops ha^{-1}

Soybean intercropping with maize has a potency to be developed in production center of maize on dryland-upland. Soybean intercropping with maize in double row with plant spacing of (40 x 20) cm x 200 cm on DLDC of Tuban District was able to produce maize seeds which were not different from maize monoculture. The intercropping also could increase LER value to 1.48-1.69. The total benefits of soybean intercropping with maize in Semanding and Merakurak could reach IDR 19.1 million and IDR 25.5 million ha^{-1}, respectively, meanwhile, the total benefits from maize monoculture reached IDR 13.9 million and IDR 24.5 million ha^{-1}, respectively. Dena 1 intercropping with maize was able to provide higher benefit, economic feasibility, as well as land-use efficiency than Argomulyo and Dega 1, even though in intercropping with maize, Dega 1 has the strongest competitiveness and Argomulyo has the higher soybean yield.

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