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Evaluation of growth and yield potential of three varieties of chili pepper (*Capsicum frutescens*) intercropped with maize (*Zea mays*) at different planting times

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Abstract. *Arta IMSD, Chozin MA, Ritonga AW. 2024. Evaluation of growth and yield potential of three varieties of chili pepper* (Capsicum frutescens) *intercropped with maize* (Zea mays) *at different planting times. Biodiversitas 25: 3985-3994.* Chili pepper (*Capsicum frutescens* L.) is a horticultural crop with high economic value. Land-use change had led to a decrease in the potential chili pepper cultivation area. One way to overcome this problem is to use intercropping, for example by planting chili peppers with maize. The purpose of this study was to determine suitable planting times and varieties for intercropping. This research was conducted with a nested design with two treatment factors. The first factor, cropping treatment, had four levels: control (chili pepper monoculture) and chili peppers planted (intercropped) at 0, 4, and 6 weeks after maize planting (MSJ). The second factor was chili variety: Bonita, Shadiva and Lobita. The sowing, soil preparation, planting, maintenance, and harvesting methods were the same for each treatment. The results of this study indicate that the 0 MSJ cropping treatment significantly increases plant height, particularly for the Shadiva variety. The Bonita variety was most productive in the 4 MSJ cropping treatment. In contrast, the control exhibited a higher incidence of geminivirus (Geminiviridae) at the same planting time. The optimal selection of planting time, in conjunction with the most suitable varieties, can enhance productivity and suppress the spread of plant diseases.

Keywords: Agroforestry, geminivirus, shading, smart farming, sustainability

Abbreviations: MSJ: Weeks after maize planting; WAP: Weeks After Planting

INTRODUCTION

Chili pepper (*Capsicum frutescens* L.) is a horticultural crop that has an important role in the Indonesian economy. Chili peppers have unique characteristics, such as their color, taste, and nutritional value. Chili pepper has high vitamin A, C, and folate contents, and its nutritional value could be increased through variety selection and plant breeding (Kantar et al. 2016) The demand for chili pepper has increased drastically, especially at the household level, resulting in a sharp increase in prices. Along with the increasing consumption of chili pepper, there has been a decrease in production caused by a decrease in the harvest area. Therefore, new ways to cultivate chili peppers need to be explored.

Crop production could be increased through intensification and optimization of currently cultivated land. For example, by utilizing the area under current crops. The cultivation of chili pepper is typically conducted in open fields under full sunlight exposure. However, it could potentially be cultivated under shaded agroforestry systems. Nurhayati and Purnamaningsih (2019) observed that certain genotypes of chili pepper exhibit low-light tolerance under teak tree canopies. The utilization of varieties that can thrive and yield well under shaded conditions is crucial for optimal land utilization beneath tree canopies; not all plants thrive and yield optimally under shaded conditions. The research conducted by Ulinnuha and Syarifah (2022) indicated that chili pepper plants experience low-light intensity or shading stress under intercropping or mixed cropping systems. Intercropping is a farming method that involves growing two or more crops on the same land (Mulu et al. 2020).

Intercropping has been introduced previously to the Indonesian agricultural landscape. Narrow land and land under tree canopies can be optimally utilized through this practice. As highlighted by Martin-Guay et al. (2018), intercropping increases farmers' gross incomes by 33% and reduces land use by 23% in comparison to monoculture farming. Similarly, Brooker et al. (2015) proposed that intercropping enhances yield without increasing inputs and provides greater yield stability with reduced inputs, thereby promoting sustainable agricultural intensification. With the shift towards modern agricultural systems, intercropping practices became less common; however, they are now being reconsidered due to limited available land. Transitioning from modern farming methods back to intercropping poses challenges, such as selecting appropriate crop combinations and timing to ensure optimal yield for each crop. Sharma and Banik (2015) demonstrated that intercropping maize and legumes in a 2:2 row ratio increased crop yield, land and time efficiency, and economic returns, thereby highlighting the potential benefits of this practice. However, over time, the intercropping system began to be replaced by a modern agricultural system. Given the limited land available, the intercropping system was reused as an intensive agricultural system. In Indonesia, particularly in the Central Java Region, 63.3% of farmers have adopted intercropping patterns involving maize and chili pepper to enhance production, optimize land use, reduce production costs, and increase farmers' incomes (Sihombing and Purnamayani 2021). Maize is used in intercropping systems with chili pepper because its natural sugar compounds help neutralize spiciness and enhance flavor complexity. Sweet corn has a higher market price than other maize types, which reflects greater production costs and consumer demand. Chili plants have different responses depending on the level of shade caused by the crown of the plant itself. Siahaan et al. (2022) found that chili plants respond both morphologically and physiologically to certain shade levels in diverse ways. Given the significant role of chili pepper in supporting Indonesia's economy and as a staple commodity for its people, this study aimed to identify the optimal planting time for chili pepper in maize intercropping systems, considering the varied responses, morphology, and production of different chili pepper varieties to low light intensities and the impact of intercropping systems on the incidence of geminivirus infection in chili pepper plants.

MATERIALS AND METHODS

Experimental design

The research was conducted at the Pasir Kuda Experimental Garden (6° 36' 30.9" S 106° 47' 03.9" E), Department of Agronomy and Horticulture, Faculty of Agriculture, Institut Pertanian Bogor, located in Bogor District, West Java, Indonesia, from the mid-dry season to the beginning of the rainy season, spanning from May 2023 to February 2024. A nested design was employed, with two factors. The first factor was cropping treatment, with four levels: chili pepper monoculture (control) and chili peppers planted (intercropped) 0, 4, and 6 weeks after maize planting (MSJ). The second factor was chili pepper variety: Bonita, Shadiva, and Lobita. Each variety was included three times.

Seed sowing

The growing medium used for seedling preparation consisted of a mixture of soil, manure, and rice husk charcoal in a 1:1:1 ratio. The seedlings were sown in seedling trays, with one to two chili pepper seeds planted in each cell. The seedling trays were placed inside a screen house. Seedling maintenance included watering every two days and applying Gandasil D fertilizer.

Land preparation

One month before transplanting, land preparation was conducted, including soil tillage, manure application, base fertilizer, and lime. The experimental field comprised 36 beds, each measuring 2.5 m × 1 m, with 1 m spacing between beds and a bed height of 30 cm. Mulch was applied to the beds designated for the monoculture cultivation of chili pepper.

Planting

Chili pepper seedlings were transplanted from the seedling trays to the field when the seedlings had reached a minimum age of five weeks and exhibited a minimum of four leaves. One plant was transplanted per hole, followed by the application of a stake. The distance between plants was 50 cm within and between rows, and maize was planted 10 cm from the chili plants (Figure 1). The chili planting was conducted in accordance with the designated treatment intervals: 0, 4, and 6 weeks after planting maize (MSJ). The planting in the control plots was conducted in parallel with the maize planting.

Maintenance

The maintenance of plants encompassed a range of activities, including watering, thinning, fertilizing, staking, weeding, and the control of pests and diseases. The plants are watered twice daily, in the morning and evening. Plants that died within one Week After Planting (WAP) were removed. Chili pepper plants were fertilized at 4, 6, and 8 Weeks After Planting (WAP) with a dosage of 75 kg ha^{-1} urea and 34 kg ha^{-1} potassium chloride (KCl). The second fertilization for maize plants was conducted at 4 WAP with 300 kg ha^{-1} of NPK fertilizer, which was applied through furrow irrigation. Staking was conducted for water shoots below the first branching on the main stem. Weeding was conducted manually around the beds. Pest control was achieved through the regular application of insecticides. Disease control was achieved through the application of fungicides on a routine and periodic basis.

Figure 1. Planting distance and timing between chili pepper and maize plants in the experimental plots

Harvest

Chili pepper fruit were considered mature when they attained a 75% red coloration and a firm texture. Harvesting was conducted every week through a selective picking process, whereby the fruit were harvested in conjunction with their peduncles. The harvesting process was conducted gradually over an eight-week period. Maize was harvested when the plants exhibited signs of readiness, such as the browning of the corn silk at the tip of the cob, the cobs being fully filled, the husks turning yellow, the seeds being dry and shiny, and leaving no imprint when pressed with a fingernail. Harvesting was conducted manually, with the cobs being picked once they reached physiological maturity or when the husks had dried.

Plant growth measurements

The plant height and stem diameter were measured weekly from 2 to 12 Weeks After Planting (WAP). These measurements were taken from the soil surface to the highest growing point. Leaf length, width, and area were observed using image analysis software on leaf samples during the first harvest. The length and diameter of fruit, as well as the weight per fruit, were observed during the third harvest using calipers. Fruitset was observed based on the number of flowers from initial growth to the final harvest, compared to the number of fruits grown from the beginning to the last harvest. The number and weight of fruit per plant were recorded from the first to the last harvest. Productivity was determined as the harvested weight per plot. The percentage of geminivirus infection was calculated based on the number of infected plants within one experimental plot. The sampling process entailed the observation of symptoms indicative of virus transmission, including leaf yellowing, curling, stunted plant growth, and a reduction in fruit quantity and quality.

Microclimate variables in the experimental field

The microclimate variables observed in this study included light intensity, air temperature, and daily air humidity. Light intensity was quantified using a lux meter at the commencement of the chili pepper planting, according to the treatment levels. The temperature and humidity of the air were monitored using a humidity and temperature data logger (Elitech RC-4HC) during the research period for each experimental plot individually.

Data analysis

The experimental data were analyzed using PKBT-STAT 3.1 with Analysis of Variance (ANOVA) at a significance level of 5%. If the ANOVA results showed a significant or highly significant effect, further analysis was carried out using the Honest Significant Difference (HSD) test at a significance level of 5%.

RESULTS AND DISCUSSION

Microclimate conditions

According to data from BMKG (2023-2024), the average rainfall for each month from May 2023 to February 2024 was 294.2, 310.7, 134.4, 144.7, 87.3, 180.7, 1133.4, 580, 395.1, and 236.5 mm, respectively. Figure 2 illustrates the microclimate conditions, including daily temperature, humidity, and light intensity, from the outset of the research until the time of maize harvest. There were no significant differences in microclimatic conditions among cropping treatments. This is likely due to the fact that maize was planted at the same time in each treatment. There was a noticeable decline in daily temperature from week 8 until week 14. However, there was a subsequent increase in temperature at week 15.

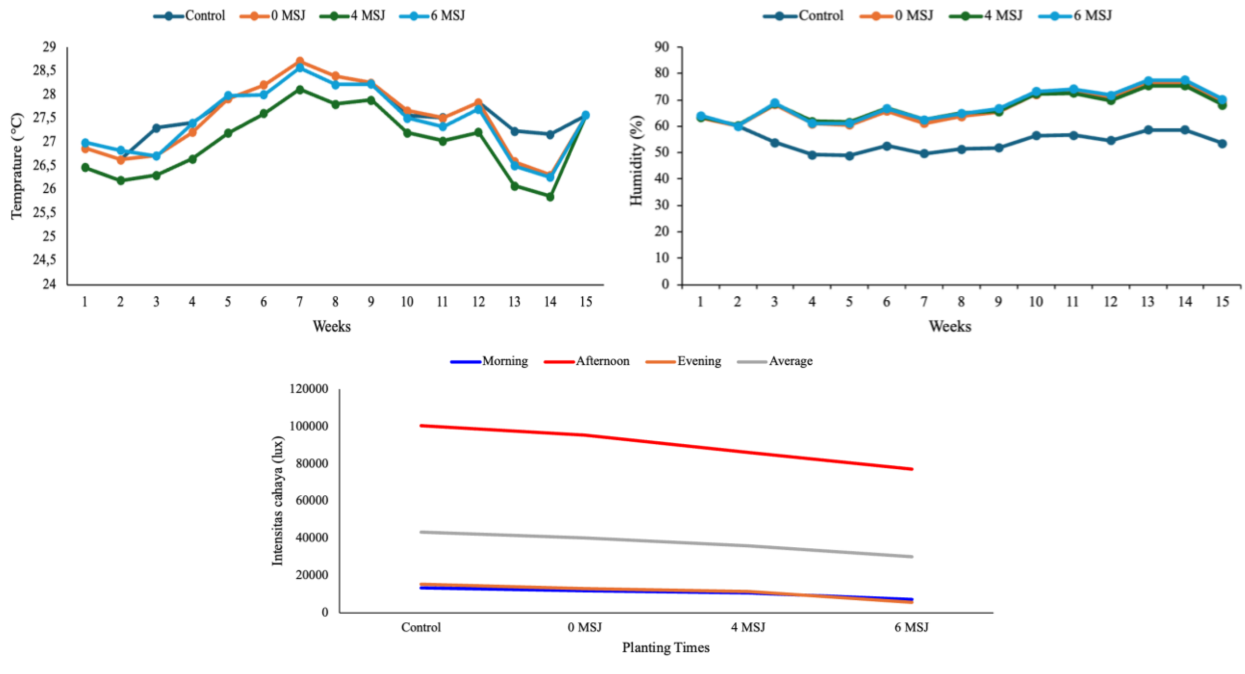

Figure 2. Microclimate data (daily temperature, humidity, and light intensity) for each chili pepper-maize cropping treatment

Humidity varied from week to week. Humidity increased from week 6 to week 14. In week 15, there was a decrease in humidity caused by the increase in daily temperature. The increase in humidity between each week was also accompanied by a decrease in light intensity between each planting time. Figure 2 illustrates the variation in light intensity based on the time of observation, specifically during the morning (07:00-09:00 GMT+7 for Jakarta, Indonesia), afternoon (12:00-14:00 GMT+7 for Jakarta), and late afternoon (16:00-18:00 GMT+7 for Jakarta). The decrease in light intensity was caused by the growing crown of maize, which began to cover the sides of the chili plants, causing the chili plants to receive less light. The 6 MSJ cropping treatment showed the lowest level of light intensity (Figure 2).

Chili pepper growth characteristics

As illustrated in Figure 3, plant height exhibited a notable increase with increasing plant age across all experimental treatments. The 0 MSJ and 4 MSJ cropping treatments exhibited a more pronounced increase than the control and 6 MSJ cropping treatments. The significant increase observed in the 0 MSJ cropping treatment could be attributed to the shading period induced by the wider maize canopy, which resulted in etiolation of the plants. Etiolation, defined as the growth of stem tissues in response to low light intensity, affects the ratio of these tissues, including the pith, cortex, phloem, and xylem. This forces plants to accelerate stem growth as an adaptation mechanism in a low-light environment (Wang et al. 2020).

The chili pepper variety and cropping treatment significantly impacted the growth characteristics of chili pepper plants. The three tested varieties exhibited notable differences in all growth parameters, except stem diameter (Table 1). The Shadiva plants were tallest, reaching 54.87 cm, significantly taller than Bonita (40.25 cm) and Lobita (41.68 cm) plants. Lobita plants had significantly larger leaves, including length, width, and leaf area, compared with the other two varieties. The observed morphological differences among the varieties could be attributed to the varying levels of adaptation of the plants to their respective environments.

Table 1. The average plant height, stem diameter, length, width, and leaf area for each variety and cropping treatment

Treatment	Plant height (cm)	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)
Variety					
Bonita	40.25±26.65^b	0.47±0.18	4.39±0.34^c	2.45±0.17^b	4.90±0.94^b
Shadiva	54.87±31.86^a	0.52±0.17	4.88±0.71^b	2.52±0.36^b	5.13±1.83^b
Lobita	41.68±25.98^b	0.51±0.17	5.00±0.79^a	2.70±0.35^a	6.11±2.26^a
Cropping treatment					
Control	29.52±0.87^b	0.30±0.04^c	4.24±0.31^c	2.37±0.08^c	3.82±0.39^c
0 MSJ	87.25±21.65^a	0.69±0.07^a	5.32±0.79^a	2.73±0.34^b	6.73±2.10^a
4 MSJ	41.51±12.01^b	0.52±0.11^b	5.10±0.49^b	2.86±0.16^a	6.79±0.87^a
6 MSJ	24.13±10.49^b	0.48±0.14^b	4.36±0.35^c	2.26±0.10^d	4.16±0.28^b

Note: Letters within each column for each factor (variety and cropping treatment) indicate significant differences based on the HSD test (α = 5%)

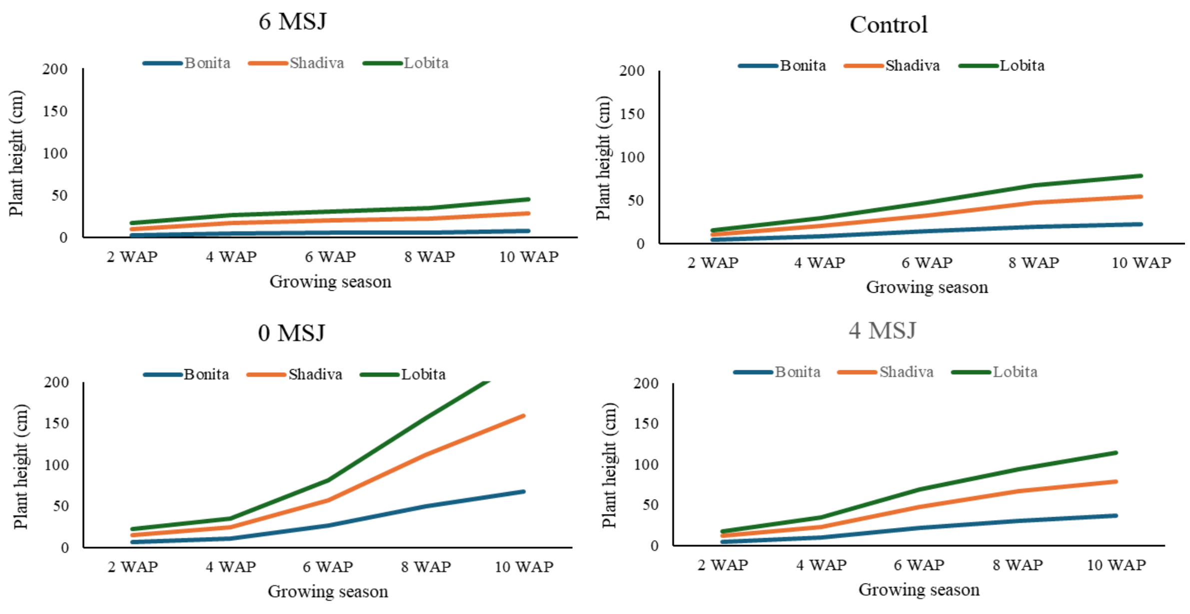

Figure 3. Chili pepper plant height based on cropping treatment

Table 2. The interaction effect of variety and cropping treatment on plant height, stem diameter, length, width, and leaf area

Variety	Cropping treatment	Plant height (cm)	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)
Bonita	Control	26.86±2.20	0.28±0.02	4.26±0.05^{g}	2.41±0.09^{ef}	4.08±0.02^{fg}
	0 MSJ	75.95±23.27	0.65±0.12	4.51±0.14^{efg}	2.46±0.06^{ef}	5.41±0.24^{de}
	4 MSJ	43.37±13.88	0.59±0.15	4.82±0.06^{d}	2.68±0.05^{cd}	6.11±0.11^{cd}
	6 MSJ	14.83±2.05	0.36±0.05	3.95±0.07^{h}	2.26±0.06^{fg}	4.00±0.18^{fg}
Shadiva	Control	34.13±4.01	0.33±0.05	3.87±0.06^{h}	2.31±0.10^{fg}	3.30±0.13^{g}
	0 MSJ	104.8±17.63	0.73±0.03	5.15±0.71^{c}	2.57±0.35^{de}	5.28±2.15^{e}
	4 MSJ	48.35±12.27	0.49±0.08	5.74±0.09^{b}	3.04±0.05^{ab}	7.88±0.48^{b}
	6 MSJ	32.22±11.93	0.53±0.16	4.76±0.10^{de}	2.15±0.05^{g}	4.04±0.12^{fg}
Lobita	Control	27.57±2.07	0.3±0.04	4.58±0.02^{def}	2.39±0.02^{ef}	4.08±0.03^{f}
	0 MSJ	80.99±21.57	0.71±0.02	6.29±0.02^{a}	3.18±0.03^{a}	9.51±0.48^{a}
	4 MSJ	32.81±6.71	0.48±0.1	4.73±0.15^{de}	2.86±0.07^{bc}	6.39±0.23^{c}
	6 MSJ	25.34±7.95	0.56±0.14	4.38±0.05^{fg}	2.37±0.05^{ef}	4.45±0.29^{f}

Note: Letters within each column indicate significant differences based on the HSD test (α = 5%)

The vegetative growth of chili peppers in the intercropping treatments was significantly higher compared to that in the monoculture (control) treatment. Additionally, increased stem diameter and leaf size accompanied the increase in plant height. In the cropping treatment where chili peppers were planted at the same time as maize (0 MSJ), the chili peppers had significantly higher plant height, stem diameter, and leaf size compared to monoculture chili peppers. The height of chili pepper plants in the 0 MSJ cropping treatment was 87.25 cm, which was significantly higher than the height of plants in the 4 MSJ (41.51 cm) and 6 MSJ (24.13 cm) cropping treatments. The stem diameter in the 0 MSJ cropping treatment (0.69 cm) was significantly different from those observed in other cropping treatments. The 6 MSJ cropping treatment resulted in the lowest mean value across all plant growth parameters, which could be attributed to the reduced shade period, resulting in the lowest light intensity received during the early vegetative phase compared to other cropping treatments within the same phase (Figure 2). The differences in growth stages between maize and chili plants lead to resource competition. Competing plants may experience reduced access to water, nutrients, and light, which are essential for photosynthesis and growth, thereby impeding their development (Robakowski et al. 2018). The use of maize canopy as shade has been demonstrated to significantly influence the growth of plants, resulting in increased plant height and diameter. As previously noted by Tchokponhoué et al. (2019), the effect of shading stimulates cell elongation and accelerates stem growth, which in turn causes the plant height and stem diameter to increase. Similar results were also found by Formisano et al. (2022), who stated that the use of shade on tomato and eggplant significantly increased stem diameter.

One of the responses observed in the intercropping treatments was an increase in leaf size, which could be due to low light intensity. The intercropping treatments resulted in significantly greater leaf sizes compared to the control (monocrop). The 0 MSJ cropping treatment resulted in a leaf length of 5.32 cm, which was significantly greater than that of the other cropping treatments. The 4 MSJ cropping treatment resulted in a leaf width of 2.86 cm, which was significantly greater than that of other cropping treatments. The leaf area of the 4 MSJ cropping treatment was 6.79 cm^2, which was not significantly different from that of the 0 MSJ cropping treatment. A plant's leaf length, width, and area are influenced by its tolerance to low light intensity and its ability to maintain photosynthesis. Liu et al. (2016) stated that plants can increase their leaf area by 55.4% in shaded conditions. The enlargement of the leaf area represents a plant adaptation mechanism to low light intensity caused by shading. This process involves elongating and expanding leaf cells, enabling light capture for photosynthesis (Tang et al. 2022).

The different chili pepper varieties and cropping treatments resulted in notable variation in leaf size (length, width, and area), while plant height and stem diameter exhibited less variation. Table 2 illustrates that the largest leaf size was observed in the 4 MSJ cropping treatment for both the Bonita and Shadiva varieties. The leaf area of the Bonita variety in the 4 MSJ cropping treatment was 6.11 cm^2, which was significantly different from that in the 6 MSJ cropping treatment (4.00 cm^2) but not significantly different from that in the 0 MSJ cropping treatment (5.41 cm^2). Similarly, the Shadiva variety in the 4 MSJ cropping treatment exhibited significantly greater leaf width than that in the other cropping treatments. The Lobita variety exhibited a greater leaf size than other varieties in the 0 MSJ cropping treatment. The leaf size of this variety, as indicated by leaf length (6.29 cm), leaf width (3.18 cm), and leaf area (9.51 cm2), was found to be significantly greater in the 0 MSJ cropping treatment than in the other cropping treatments. The observed differences in leaf size among the varieties under each cropping treatment indicate their capacity to adapt to low light intensity with a longer shaded period. The application of shade to plants can influence leaf size by modifying the flow of nutrients from the stem to the leaves. Additionally, plants may exhibit a shade avoidance response towards the light source, which can result in alterations in leaf size, including increased length, widening, and expansion of leaves to maximize light absorption (Chitwood et al. 2015). The same results were observed by dos Santos et al. (2015) in their research on *Commelina benghalensis* L. and *Cyperus rotundus* L. weed species. It was found that prolonged shade can induce an increase in leaf size, but it can also reduce leaf thickness and area. However, in shady conditions, leaf area can increase significantly. In response to shading, plants tend to avoid areas without exposure to sunlight, directing their growth towards the light source. This process involves the expression of specific genes in plant development pathways related to the formation and increase in leaf size (Fiorucci et al. 2022).

Chili pepper yield characteristics

As shown in Table 3, there were significant differences among the three varieties in all yield characteristics, except for fruit diameter. As reported by Chowdhury et al. (2023), chili peppers exhibit considerable variability in fruit size, fruit weight, number of fruits per plant, and productivity. The Lobita variety exhibited a significantly lower fruitset (53%) compared to the Shadiva (74%) and Bonita (92%) varieties. The Lobita variety is commonly utilized in the arid regions of East Java, Indonesia, where precipitation is relatively scarce. The high rainfall in Bogor, West Java, Indonesia, ranging from 87.3 to 1133.4 mm during the study period from May 2023 to February 2024 may have contributed to a fruit reduction. In addition to the average fruitset, the lowest number of fruits per plant was observed in the Lobita variety (34.06 fruit) (Figure 4), while the highest was noted in the Bonita variety (94.86 fruit). Despite the low number of fruits, the Lobita variety exhibited the highest fruit diameter (1.61 cm) and a significantly higher fruit weight (3.21 g) than the Shadiva (2.88 g) and Bonita (2.33 g) varieties.

Table 3 also indicates that low light intensity due to maize shading significantly reduced the number of fruits per plant and fruit size. The number of fruits per plant in intercropping ranged from 45.93 to 65.52, which was lower than that observed in monocropping (88.74). The lowest number of fruits was observed in the 6 MSL cropping treatment, which also had the highest level of shade. A similar trend was observed in fruit weight per plant and fruit length. The lowest recorded fruit weight was 2.72 g, which was observed in the 6 MSJ cropping treatment. During the period of reduced light intensity, specifically the early vegetative phase, the 6 MSJ cropping treatment exhibited the lowest light intensity compared to other cropping treatments within the same phase. As noted by Nagy et al. (2017), the application of shade has a notable influence on the characteristics of chili fruit. Other studies have yielded different results for bell pepper plants. Díaz-Pérez et al. (2020) indicated that using shade can enhance the quality and yield of bell peppers compared to unshaded conditions. However, it has been demonstrated that shaded conditions do not increase fruit weight or the number of fruits per plant.

Table 3. The average length, fruit diameter, weight per fruit, fruitset, and number of fruits per plant for each variety and cropping treatment

Treatment	Fruitset (%)	Number of fruits per plant (fruit)	Fruit length (cm)	Fruit diameter (cm)	Weight per fruit (g)
Variety					
Bonita	92±0.06[a]	94.86±26.87[a]	3.44±0.07	1.18±0.30[c]	2.31±0.31[c]
Shadiva	74±0.09[b]	68.86±24.57[b]	3.48±0.14	1.35±0.46[b]	2.88±0.36[b]
Lobita	53±0.14[c]	34.06±15.29[c]	3.38±0.17	1.61±0.51[a]	3.21±0.25[a]
Cropping treatment					
Control	76±0.23	88.74±35.26[a]	3.40±0.15[a]	1.4±0.28	3.10±0.43[a]
0 MSJ	78±0.09	63.52±16.89[bc]	3.72±0.2[a]	1.33±0.24	2.40±0.50[d]
4 MSJ	69±0.24	65.52±43.51[b]	3.59±0.27[a]	1.4±0.30	2.98±0.47[b]
6 MSJ	69±0.19	45.93±21.75[c]	3.03±0.29[b]	1.38±0.51	2.72±0.23[c]

Note: Letters within each column for each factor (variety and cropping treatment) indicate significant differences based on the HSD test (α = 5%)

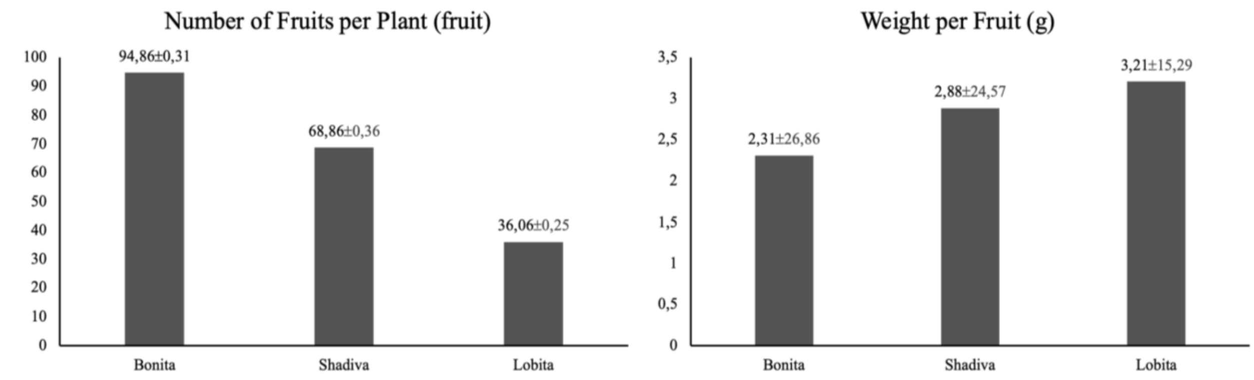

Figure 4. Graph of number of fruits per plant and weight per fruit for each variety

Table 4. The interaction effect of variety and cropping treatment on fruitset, number of fruits per plant, length, diameter, and weight per plant

Variety	Cropping treatment	Fruitset (%)	Number of fruits per plant (fruit)	Fruit length (cm)	Fruit diameter (cm)	Weight per fruit (g)
Bonita	Control	98±0.01[a]	118.11±10.20[a]	3.1±0.06	1.23±0.26[ef]	2.53±0.05[d]
	0 MSJ	85±0.05[ab]	75.00±19.72[bc]	3.53±0.06	1.13±0.15[f]	1.80±0.05[e]
	4 MSJ	96±0.03[a]	118.00±12.44[a]	3.77±0.1	1.20±0.23[ef]	2.43±0.08[d]
	6 MSJ	88±0.05[ab]	68.33±7.77[bc]	3.37±0.06	1.13±0.11[f]	2.48±0.01[d]
Shadiva	Control	81±0.11[ab]	101.56±21.75[ab]	3.5±0.11	1.53±0.17[abcd]	3.38±0.01[a]
	0 MSJ	78±0.12[ab]	67.89±5.84[bc]	3.87±0.1	1.30±0.23[cdef]	2.45±0.29[d]
	4 MSJ	67±0.08[bcd]	57.89±13.34[cd]	3.47±0.15	1.27±0.35[def]	3.01±0[b]
	6 MSJ	71±0.05[bc]	48.11±12.25[cd]	3.1±0	1.30±0.7[cdef]	2.68±0.01[c]
Lobita	Control	49±0.09[cd]	46.56±13.62[cd]	3.6±0.06	1.43±0[bcde]	3.40±0.08[a]
	0 MSJ	71±0.09[bc]	47.67±7.69[cd]	3.77±0.06	1.57±0.15[abc]	2.95±0[b]
	4 MSJ	44±0.13[d]	20.67±1.85[d]	3.53±0.06	1.73±0.32[a]	3.50±0.02[a]
	6 MSJ	48±0.11[cd]	21.33±3.75[d]	2.63±0.26	1.70±0.35[ab]	3.01±0.05[b]

Note: Letters within each column indicate significant differences based on the HSD test (α = 5%)

Siahaan et al. (2022) and Alhidayah et al. (2024) observed that each variety of chili exhibits distinct morphological and physiological responses to low light intensity due to shading. The current study's findings indicate an interaction between chili pepper variety and cropping treatment concerning yield characters, as detailed in Table 4. The Bonita variety exhibited a high yield potential, with a notable decrease in the number of fruits when intercropped with maize in the 0 MSJ and 6 MSJ cropping treatments, but no difference between the 4 MSJ intercropping treatment (average number of fruits: 118.0) and the control monoculture treatment (average: 118.11). The Bonita variety in the 4 MSJ cropping exhibited a high fruitset (96%), but it was not significantly different from the control (98%). This pattern was also observed in fruit diameter and fruit weight. This indicates that for the Bonita variety, the optimal planting period in an intercropping system with maize is 4 MSJ. Farmers in the Blitar area of East Java, Indonesia, employ the intercropping method at 4 MSJ to enhance local farm productivity and financial stability. Gustiar et al. (2023) observed that the use of shade by the chaya plant (*Cnidoscolus aconitifolius* (Mill.) I.M.Johnst.) reduced leaf temperature and suppressed chili plant growth. However, this was accompanied by an increase in growth and yield following canopy pruning, particularly for the chili variety Bara. Incorporating maize as a peripheral plant can enhance the number of plants per hectare and is associated with an increase in chili plant yield (Devy et al. 2021).

Compared to the Bonita variety, the Shadiva variety responded differently to shading. In general, shading had a negative effect on the yield components of chili plants. Indeed, the result showed that with increasing shade levels, the average number of fruits produced per plant tended to decrease (Table 4). The mean number of fruits produced by the Shadiva variety in monoculture was 101.56, while in intercropping, it decreased to 67.89 (0 MSJ), 57.89 (4 MSJ), and 48.11 (6 MSJ). For the Lobita variety, there was no difference in yield between intercropping at the same time as maize planting (0 MSJ) and the control. When planted at a late stage (4 MSJ and 6 MSJ), there was a significant reduction in the number of fruits per plant compared to the control (monoculture). The mean numbers of fruits produced by these varieties in the 0 MSJ cropping treatments were 47.67, which were not significantly different from those produced in the monoculture (control) treatments. The mean number of fruits produced in the 4 and 6 MSJ cropping treatmetns was 20.67 and 21.33, respectively, which was lower and significantly different from that produced in the control treatment. These findings showed that the Lobita variety may offer greater profitability when intercropped with maize at the same planting time.

Yield components of chili pepper and percentage of plant disease infestation

Similar to the vegetative growth and fruit characteristics, there was significant variation among the varieties tested for yield components. The highest fruit weight per plant was observed for the Bonita variety (222.28 g), which was significantly different from that for the Lobita variety (108.66 g). However, no statistically significant difference was observed between the Bonita variety and Shadiva variety (203.16 g). The yield components and productivity of chili plants are influenced by several factors. These include genetic variability, weather conditions, and nutrient source management. Genetic diversity has been demonstrated to have a significant impact on productivity, particularly when genetic breeding approaches are employed (Negi and Sharma 2019). The planting time of chili in an intercropping system also has a significant impact on the weight of fruit per chili plant and overall productivity. The presence of shade in intercropping systems has been observed to reduce the average fruit weight per plant. In the current study, the fruit weight per plant in the intercropping systems ranged from 120.77 to 147.35 g, which was lower than the weight observed in the monoculture system (266.31 g).

Figure 5. Illustrates the effects of a geminivirus on two chili leafes. Leaf (A) which was not exposed to the virus, remains uninfected; while Leaf (B) displays symptoms consistent with the virus's presence

Table 5. Average fruit weight per plant, productivity, and percentage of pest attack for each variety and cropping treatment

Treatment	Fruit weight per plant (g)	Productivity (t ha^{-1})	Spread of geminivirus (%)
Variety			
Bonita	222.28±78.67^{a}	7,77±2.67^{a}	9.17±18.81
Shadiva	203.16±94.94^{a}	6,39±1.61^{a}	15±18.82
Lobita	108.66±47.88^{b}	3,76±1.51^{b}	10±17.58
Cropping treatment			
Control	266.31±94.92^{a}	6,42±2.27^{ab}	38.89±13.64^{a}
0 MSJ	147.35±27.86^{bc}	5,74±0.96^{bc}	2.22±4.41^{b}
4 MSJ	177.71±96.78^{b}	7,11±3.87^{a}	0.00±0^{b}
6 MSJ	120.77±49.95^{c}	4,63±2.05^{c}	4.44±8.82^{b}

Note: Letters within each column for each factor (variety and cropping treatment) indicate significant differences based on HSD test (α = 5%)

It is commonly known that intercropping systems can not only enhance land productivity, but also deter the infestation of pest organisms. Kermah et al. (2017) and Pariz et al. (2020) indicated that intercropping maize and beans can enhance bean yields while simultaneously exerting a significant influence on weed, pest, and disease management. Furthermore, intercropping offers a higher profit potential for small farmers in developing countries. Ollo et al. (2022) posited that the shaded environment effect of agroforestry systems exerts a suppressive influence on pests and diseases, affecting pest performance and soil conditions to render them inhospitable to pests. Observations of the intensity of geminivirus attack in numerous chili plantations in Indonesia indicated that they exhibit a similar susceptibility to geminivirus attack, with approximately 10-15% of the population infected with this virus (Table 5). The current study yielded intriguing findings, including evidence that intercropping systems can mitigate virus attacks on chili peppers. The intensity of the geminivirus attack on chilies grown in monoculture was 38.89% higher and significantly different from that in the intercropping treatments. In the 4 MSJ intercropping treatment, no virus attack was observed. The intercropping of chili peppers with maize has been demonstrated to significantly suppress anthracnose disease (*Gloeosporium piperatum* Ellis & Everh.) and delay disease attack, making it a sustainable agricultural alternative to the continuous use of chemical fungicides (Gao et al. 2021). Intercropping systems can reduce geminivirus infections by decreasing the population of virus vectors and lowering the likelihood of widespread virus transmission through plant diversity and asynchronous life cycles (Huss et al. 2022).

The response of chili varieties to shade caused by intercropping is demonstrated by differences in fruit weight per plant and productivity. The highest average fruit weight of chili pepper in the intercropping systems was obtained in the 4 MSJ cropping treatment (286.5 g; Table 6) and was not significantly different from that in the monoculture (control) treatment (298.34 g). These findings align with the findings of Siahaan et al. (2022), which indicated that the Bonita variety exhibits the highest average fruit weight per plant in shaded conditions, though it is not significantly different from conditions without shade. From an economic standpoint, this intercropping strategy is highly profitable, as it allows farmers to cultivate both chili and maize crops. The presence of shaded maize plants significantly reduced fruit weight per plant for all treatments in the case of the Shadiva variety. It appears that this variety is particularly susceptible to shade. Siahaan et al. (2022) and Alhidayah et al. (2024) indicate that shade significantly reduces fruit weight per plant. Concerning the Lobita variety, which is a local variety originating from Blitar, East Java, Indonesia, the fruit weight per plant in the 0 MSJ intercropping treatment was 140.55, which was not significantly different from that in the control treatment (157.47 g).

Table 6. The interaction effect between cropping treatment and variety on fruit weight per plant, productivity, and percentage of pest attack

Variety	Cropping treatment	Fruit weight per plant (g)	Productivity (t ha^{-1})	Spread of geminivirus (%)
Bonita	Control	298.34±25.07^{a}	7.44±2.03^{b}	36.67±20.81
	0 MSJ	134.81±33.95^{bc}	5.39±1.36^{bcd}	0±0
	4 MSJ	286.65±36.51^{a}	11.46±1.46^{a}	0±0
	6 MSJ	169.32±18.84^{bc}	6.77±0.75^{bc}	0±0
Shadiva	Control	343.11±73.43^{a}	7.66±0.78^{ab}	43.33±5.77
	0 MSJ	166.68±5.81^{bc}	6.41±0.32^{bcd}	3.33±5.77
	4 MSJ	174.14±40.10^{b}	6.96±1.60^{b}	0±0
	6 MSJ	128.72±32.42^{bc}	4.54±1.65^{bcd}	13.33±11.55
Lobita	Control	157.47±43.16^{bc}	4.16±2.05^{bcd}	36.67±15.27
	0 MSJ	140.55±22.57^{bc}	5.41±0.71^{bcd}	3.33±5.77
	4 MSJ	72.33±6.95^{bc}	2.89±0.27^{cd}	0±0
	6 MSJ	64.28±12.50^{c}	2.57±0.50^{d}	0±0

Note: Letters within each column indicate significant differences based on the HSD test (α = 5%)

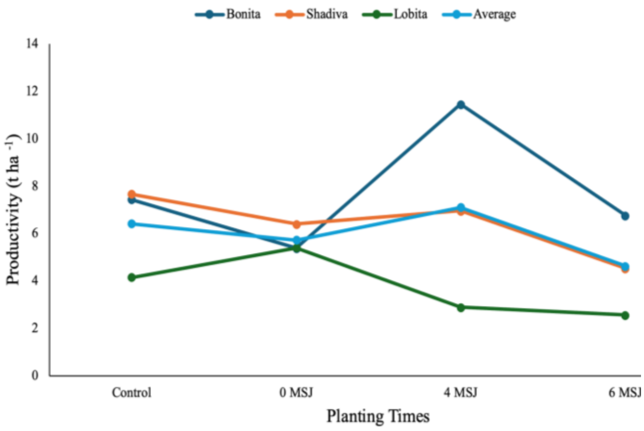

Figure 6. The interaction between chili pepper variety and cropping treatment on chili pepper productivity

The utilization of suitable varieties combined with optimal planting time has a profound impact on the yield of chili. Figure 6 illustrates that the average productivity of the Bonita variety was highest in the 4 MSJ cropping treatment, whereas the opposite result was observed for the Lobita variety. The productivity of the Bonita variety in the 4 MSJ cropping treatment was significantly higher compared to that of other varieties in other cropping treatments. These results indicate an interaction between variety and cropping treatment.

In conclusion, an experiment was conducted on three varieties of chili pepper to ascertain their responses to shade caused by intercropping with maize. The optimal planting time for the Bonita variety was 4 weeks after planting maize (MSJ). The optimal planting time for the Lobita variety, which is a local variety, was the same as that for maize planting (0 MSJ). The intercropping systems significantly reduced the incidence of geminivirus disease in chili plants. Further research is necessary to identify suitable and high-yielding types of maize that can be combined with the Bonita chili variety, which was most productive when planted 4 weeks after maize planting (MSJ).

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