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Effect of Water Spinach Spacing and Planting Time on Chili Growth in Chili-Water Spinach Intercropping

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ABSTRACT

Chili is one of the horticulture crops with the highest commercial value. Farmers can cultivate chili in intercropping systems with water spinach plants as a land-saving alternative. The purpose of this study was to determine the optimal chili planting distance and water spinach planting timing for increasing chili plant growth in chili-water spinach intercropping cultivation. A factorial randomized group design was adopted in this study. The first consideration was the spacing between the chili plants, which measure 50×70 cm and 50×50 cm, respectively. The second aspect was to plant water spinach at the same time as chili, one week after planting (1 WAP) chili, and 2 WAP chili. The findings indicate that optimum spacing and planting time for water spinach can improve the growth of chili plants. When chili plants were spaced 50×70 cm apart, their height and number of leaves increased dramatically. When compared to other treatments, the planting time of water spinach 1-2 WAP chili resulted in significantly higher plant height and number of leaves. All growth variables examined were significantly influenced by the interaction of 50×70 cm and water spinach planting time 2 weeks after chili planting.

Keywords: chili, intercropping, planting distance, planting time, water spinach

INTRODUCTION

Intercropping is a planting method that involves growing more than one variety of plant in the same area, commonly used on both big and small plots of land. Overlapping land usage offers various benefits, including improving farmers' revenue, lowering the probability of crop failure in one of the commodities, increasing land tillage efficiency, and making better use of available land. However, the intercropping pattern has a disadvantage in that it promotes competition for food supplies such as nutrients, water, and sunlight. The identification of primary crops and intercropping can serve as the foundation for intercropping patterns. Intercropping with two or more plants will result in interaction since living plants require adequate growth area to optimize the concept of collaboration between plants while minimizing competition (Feng *et al*. 2022). As a result, numerous factors must be addressed in the intercropping pattern, including planting distance, plant population size, harvest age, and planting time. Intercropping can enhance competition between plants in growth factors, therefore to limit and slow the rate of competition, modify the planting spacing for the main crop, and the planting period for intercropping.

Chili (*Capsicum frutescens* L.) is an example of a plant that can be grown in rice fields with an intercropping arrangement as the main crop. Chili is a horticultural crop and a food item that is widely grown and processed into dry chili goods, chili sauce, chili powder, and frozen chili. This plant has considerable economic value and can potentially be used as a non-oil and gas export commodity (Aminah *et al*. 2022). The major element of chili is exported not only in the form of fresh products, but also as processed dried chili or powder, which can be kept and held for an extended period of time. According to BPS vegetable production data (2022), the production of chili increased from 578,883 tons in 2021 to 646,740 tons in 2022. Meanwhile, Ziaulhaq and Amalia (2022) stated that the community consumes 80% of chili and requires 20% of it for industrial purposes. The high level of chili consumption must be matched by an increase in plant output to ensure that the community and industry's needs are met. Planting distance is used to determine the population, the closer the planting distance will increase the number of plant populations. Yumte *et al*. (2023) said that adjusting the appropriate planting distance will reduce competition between plants in terms of the use of nutrients, water, sunlight, and growing space.

Water spinach (*Ipomoea reptans*) can be used as a cover crop or to reduce weeds that interfere with chili production. Water spinach, as an intercropping, has a shorter harvest life than chili, so farmers can use it to generate money while they wait for the chili harvest. The timing of water spinach planting as an intercropping attempts to avoid rivalry between plants, since the faster development of water spinach

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compared to chili is the primary reason for distinguishing the time of planting. Planting period in an intercropping design is related to vegetative growth; water spinach plants develop quicker than chili, thus they will dominate the growing space (Qomah *et al*. 2021). Furthermore, water spinach are among the most extensively consumed vegetables in the community; there is no age limit for consuming water spinach, so farmers may utilize it for their daily needs in addition to earning extra money.

The planting spacing of chili plants, as well as the planting timing of water spinach as an intercrop, must be addressed to ensure that there is no rivalry for water, nutrients, and sunlight, hence increasing chili plant productivity. Based on this background, we undertake research on the regulation of differences in chili planting distance and water spinach planting time to evaluate chili growth and yield in an intercropping system.

METHODS

Time and Place

The research was carried out in January-June 2023 in Dusun Klitih, Wajik Village, Lamongan District, Lamongan Regency. The average temperature was 20–32°C, the average rainfall was 1,500–3,000 mm, and clay type soil.

Procedure

The seeds used were chili seeds from the Dewata 43 F1 variety and water spinach from the Bangkok LP-1 variety. Tillage was used to prepare the land, and treatment plots of 1 m × 3 m were created. One week before planting, NPK basic fertilizer was applied at a dose of 1 kg/plot, followed by 4 kg/plot of cow manure. Follow-up fertilizers were applied to chili at 2 weeks after planting (WAP) and 4 WAP, with a dose of 10 g/plant of NPK and Urea, respectively. Planting distances for chili were 70 cm × 50 cm and 50 cm × 50 cm, respectively, depending on the treatment. Water spinach was planted in accordance with the treatment, which was at the same time as chili, one week after, and two weeks following chili. The chili planted were seedlings that have grown 2 weeks. Water spinach seeds were planted, with 3 seeds per planting hole. Chili was harvested in stages based on the physiological ripeness of the chili. Water spinach was harvested according to physiological age.

Experimental Design

This study employed a Factorial Group Random Design, with the first factor being chili planting spacing 50 cm × 70 cm and 50 cm × 50 cm. The second factor was the timing of planting water spinach: at the same time as planting chili, one week later, or two weeks later. The combination of treatments was in triplicates, yielding 18 experimental units.

Observation Variables

Observations were made on chili plants, including the number of leaves measured every 2 weeks beginning at the age of 2 WAP and counting all leaves fully open. Plant height (cm) was measured every 2 weeks, beginning at 2 WAP age, from soil level to crown.

Data Analysis

The observation data were provided as averages and confidence intervals for three treatment replicates. The normality of the data was determined using the Shapiro-Wilk test. The data's homogeneity was assessed using the Levene statistical test. To determine the effect of each treatment, the One-Way Analysis of Variance (ANOVA) test was employed. If there is a significant difference, the test was continued using Duncan's Multiple Range Test (DMRT) with a significant level of 5% and a $P < 0.05$ using the SmartstatXL application.

RESULTS AND DISCUSSION

The findings of the recapitulation of variance such as chili planting distance and water spinach planting time revealed substantial differences in the number of leaves and height of chili plants (Table 1).

Growth Response of Chili Plants at Planting Distance

The plant height variable showed a very meaningful difference between observations 2 and 6 WAP, no difference at 8 WAP, significant difference at 10 WAP, and highly different at 12 WAP (Table 2). The treatment that produces the best outcomes at all observation ages is planting cayenne pepper at 70 cm × 50 cm. According to Qibtiyah *et al*. (2021), one of the factors influencing plant development and yield is planting density. Planting spacing affects nutrient absorption in the soil as well as sunlight absorption by the foliage. A close planting distance will result in a large plant population in each area. The huge population will have an impact on plant competitiveness for nutrients. The higher the plant population, the fewer nutrients are absorbed. Nutrient deficit can impede plant growth, resulting in a smaller plant size and less plant assimilates (photosynthesis products) (Warman and Kristiana 2018). Plants with a close planting distance have less optimal solar absorption during their growth phase. This can occur because in plants with too tight planting intervals, not all parts of the plant are exposed to sunlight, particularly the leaves, which play a vital role in absorbing sunlight.

Table 1 Recapitulation of the analysis of the variation of chili planting distance and water spinach planting time on the growth of chili plants

Variable	Chili planting distance (50 cm × 50 cm, 50 cm × 70 cm)		Water spinach planting time (1 WAP, 2 WAP)		Interaction	
Plant height 2 WAP	25.35	**	11.70	**	4.70	*
Plant height 4 WAP	16.66	**	95.22	**	6.29	*
Plant height 6 WAP	137.68	**	245.62	**	5.95	*
Plant height 8 WAP	0.05	tn	24.23	**	8.63	**
Plant height 10 WAP	5.91	*	43.49	**	13.11	**
Plant height 12 WAP	21.09	**	20.27	**	4.17	*
Number of leaves 2 WAP	2.12	tn	3.69	ns	44.13	**
Number of leaves 4 WAP	43.80	**	331.43	**	7.18	*
Number of leaves 6 WAP	62.47	**	47.36	**	25.38	**
Number of leaves 8 WAP	29.94	**	3071.83	**	151.89	**
Number of leaves 10 WAP	55.76	**	1141.65	**	98.61	**
Number of leaves 12 WAP	9.90	*	7980.50	**	1021.48	**

Remarks: ns = Insignificant effect, ** = Very significant effect, * = Significant effect on the 5% *F* test. WAP = Week after planting.

Table 2 Chili plant height at various planting distances

Planting distance	Plant height (cm)											
	2 WAP		4 WAP		6 WAP		8 WAP		10 WAP		12 WAP	
50 cm x 70 cm	11.11	b	18.23	b	26.56	b	30.18		36.83	b	41.57	b
50 cm x 50 cm	9.96	a	17.22	a	24.11	a	30.09		36.07	a	39.52	a

The varied number of leaves reflects the plant's height. According to analysis, the observed ages of two WAPs were not significantly different. The observation age of 4–12 WAP reveals a significant variation, with the best number of leaves found at a planting spacing of 50 cm × 70 cm (Table 3). The planting distance of 50 cm × 70 cm allows plants to grow and develop efficiently. The planting distance can condition every area of the plant so that it is exposed to sunshine and can absorb nutrients as efficiently as possible. According to Olahairullah (2022), proper planting spacing can limit competition between the intercropped plants for nutrients, water, sunlight, and growing space.

The study's findings revealed a decrease in the number of leaves in the 50 × 50 cm close planting distance treatment at the 12 WAP period. This phenomenon is explained by the effect of plant population density on individual plant growth. Plants compete more intensely for important resources such as sunlight, water, and nutrients as their population density increases (Issaka *et al*. 2023; Postma *et al*. 2020). This competition causes a drop in plant photosynthesis rates, which has a direct impact on leaf growth and development. Furthermore, the shadowing impact of the leaves between plants contributes to a decrease in the number of leaves. Shading limits the amount of sunlight received by the plant, which inhibits photosynthesis and the production of new leaves. Thus, the reduction in the number of leaves at close planting spacing is a physiological reaction of plants to resource constraints caused by increasing competition.

The reduction in the number of leaves seen in the 50 cm × 50 cm planting distance treatment can also be linked to changes in plant biomass allocation. Plants prefer to allocate more biomass to organs that are vital for their survival, such as roots and leaves, when populations are dense (Wei 2021). As plants attempt to extend the reach of their roots and boost their intake of water and nutrients from the soil, they allocate more biomass to them. Meanwhile, biomass allocation to leaves is increasing to maximize restricted sunlight absorption due to competition. However, this enhanced allocation of biomass to roots and leaves comes at the expense of growth in other organs such stems and reproductive organs (Wang *et al*. 2021). As a result, the plant's overall growth, including the creation of new leaves, is hindered. This phenomenon demonstrates a trade-off in the allocation of plant resources as an adaptive response to high population density, which ultimately leads to a decrease in the number of leaves at close planting distances.

Growth Response of Chili Plants at the Time of Planting Water Spinach

The height of chili plants at the age of 4–10 WAP showed the greatest significant difference, specifically in the treatment of the water spinach planting time of 2 WAP of chili, whereas at the age of 12 WAP there was no significant difference with the treatment of the water spinach planting time after 1 WAP of chili (Table 4). Planting of main crops interrupted by 1–2 weeks results in the best plant height due to optimal nutrient distribution for the plants. The variation in planting time is intended to improve the efficiency of fertilizer utilization in intercropping agriculture systems (Warman and Kristiana 2018). Planting the main crop within 2 weeks of intercropping allows for the division of available nutrients. During the first 2 weeks of chili growth, all available nutrients will be fully consumed. Chili plants adjust to new land conditions over the first 2 weeks. This circumstance has a greater impact than growing intercropping plants simultaneously. When intercropping plants are planted together, they compete for nutrients, water, and sunlight to grow. This is because both plants are in the same growth phase. This rationale significantly influences how varied planting timings are treated in the intercropping system. According to Arma *et al*. (2013), delaying the planting period of one variety of intercropped plant is designed to ensure that maximum growth occurs at separate times. This will aid efforts to maximize the production potential of the intercropped crops (Table 5).

The varying number of leaves produced the same outcome as the plant's height. The observation age of 2 WAP showed no meaningful change, whereas the observation age of 4–12 WAP indicated a significant difference in the treatment of the water spinach planting period of 2 WAP chili (Table 4). Intercropping 2 weeks apart from the main plant allows for optimal plant growth and development. In the absence of unutilized nutrients, nutritional absorption will continue to be optimized. After being used for the plant's height growth, the remaining nutrients will be used to construct branches that will eventually produce leaves. Furthermore, the available nutrients will be utilized in the leaf production process. In addition to receiving water and nutrients from the soil through their roots, newly formed chili plants' leaves absorb sunlight for photosynthesis. Intercropping, which involves planting at different periods, can help to lessen competition (Pertiwi and Gosal 2019). This is since the overlapping plants are not planted at the same time, making it simple to arrange the plant sections so that there is no overlap.

The decrease in the number of chili leaves at the age of 12 WAP after planting water spinach and 2 WAP chili had no significant effect on chili plants' growth. Although water spinach planted 2 WAP after chili planting achieves optimal growth at the age of 8 WAP, or 6 WAP after chili planting (ul Haq *et al*. 2020), this has no negative impact on the critical time of chili development. Chili plants undergo the fruit development and filling phase, also known as the harvest phase, when they reach 12 WAP (Nurjannah *et al*. 2021). During this period, chili plants' resource requirements begin to decrease as energy is allocated for fruit production. As a result, competition between chili and water spinach plants during the water spinach's peak growth period has no effect on chili yield. Although the quantity of chili leaves decreased, it had no significant impact on chili yield.

Water spinach's optimal growth at 8 WAP has no substantial shade influence on chili plants that have entered the fruit production and filling phase (ul Haq *et al*. 2020). A denser canopy of water spinach leaves in its ideal growth period does not significantly diminish the amount of sunlight received by chili leaves, as chili have already passed through the vegetative growth phase, which requires more sunlight. Furthermore, chili's well-developed root system can successfully compete with water spinach roots for soil water and nutrients (Postma *et al*. 2020). This demonstrates that chili plants may adjust well to the presence of water spinach plants planted 2 weeks later. However, determining the correct planting distance between chilis and water spinach is still necessary to promote good development and productivity for both plants in an intercropping system (Nurjannah *et al*. 2021). Proper spacing can reduce competitiveness while increasing

Table 3 The number of chili leaves at various planting distances

Planting distance	Number of leaves									
	2 WAP	4 WAP		6 WAP		8 WAP		10 WAP	12 WAP	
50 cm x 70 cm	12.88	35.72	b	178.96	b	647.23	b	716.63	720.12	b
50 cm x 50 cm	12.49	33.53	a	151.70	a	603.65	a	739.51	706.01	a

Table 4 Chili plant height at various times of planting water spinach

Water spinach planting time	Plant height (cm)											
	2 WAP		4 WAP		6 WAP		8 WAP		10 WAP		12 WAP	
0 WAP chili	10.92	b	16.13	a	23.60	a	28.48	a	34.58	a	38.58	a
1 WAP chili	10.94	b	16.96	b	23.79	a	29.97	b	36.58	b	41.17	b
2 WAP chili	9.75	a	20.08	c	28.60	b	31.95	c	38.19	c	41.88	b

Table 5 The number of chili leaves at various times of planting water spinach

Water spinach planting time	Number of leaves										
	2 WAP	4 WAP		6 WAP		8 WAP		10 WAP		12 WAP	
0 WAP chili	12.33	32.42	b	159.72	b	448.45	b	535.67	b	464.31	a
1 WAP chili	13.18	30.88	a	148.17	a	363.75	a	492.94	a	565.73	b
2 WAP chili	12.53	40.58	c	188.11	c	1,064.11	c	1,155.60	c	1,109.15	c

resource consumption, resulting in peak productivity for both plants (Megersa and Banjaw 2024).

Growth Response of Chili Plants on the Interaction of Planting Distance and Water Spinach Planting Time

The distance of planting chili and the time of planting water spinach have a significant impact on the high growth phase of chili plants. At the start of the tall growth of chili plants, the planting distance of 50 cm × 70 cm with the planting time of water spinach is 1–2 WAP, the chili shows a significant difference compared to the planting distance of 50 cm × 50 cm with the planting time of the same water spinach (Figure 1a-c). This is most apparent toward the conclusion of the observation, which is 12 WAP (Figure 1d-f). The planting space of 50 cm × 70 cm, as well as the two-week variation in the planting period of water spinach, can improve plant nutrients absorption. According to Lestari *et al*. (2019), planting timing in an intercropping system is critical throughout the vegetative growth phase. The first 2 weeks of nutrients will be optimized for the growth of chili plants. Chili is the primary crop grown earlier than water spinach in the treatment of water spinach planting time. 2 WAP chili has passed the critical period phase and is ready to compete, but newly planted water spinach is still in the critical period phase and requires additional nutrients for growth. Pratama and Agus (2022) define the crucial time as the maximum period after which the presence of weeds or other plants has no effect on the final production.

According to Figure 2, the number of chili leaves is ideal at the age of 4–5 WAP. The planting distance of 50 cm × 70 cm and 50 cm × 50 cm chili, together with a water spinach planting time of 2 WAP chili, influences the increase of leaf development of chili plants up to the observation age of 12 WAP (Figure 2). A tight planting distance of 50 cm × 50 cm combined with a planting time of 2 WAP chili will result in nutrient competitiveness between plants, but chili is enough to increase the number of leaves even though it is not as effective as a planting distance of 50 cm × 70 cm. This is related to the impact of plant population density on a given geographical area. A longer planting spacing will result in more leaves since the intensity of sunlight absorbed by the plant affects the photosynthetic output produced. Increased photosynthate production will speed up the formation of plant organs like leaves. The optimal number of leaves promotes a more balanced dispersion of sunlight between them. A more uniform distribution of sunlight between leaves minimizes the likelihood of shadowing. The physiology of the F1 good variety chili plant, which has the potential for increased branch growth and hence affects the quantity of leaves generated. This is also consistent with the growth of plant height, with a planting distance of 50 cm × 70 cm and a planting time of 2 WAP, chili gave the highest crop height. The number of branches rises as the plant grows in height. Branches are where leaves grow, so the more branches, the more leaves.

CONCLUSION

The regulation of chili planting spacing and water spinach planting timing has a major impact on chili plant growth in chili-water spinach intercropping production. The planting space of 50 cm × 70 cm significantly improves plant height and the number of chili leaves. The planting period of water spinach 1–2 WAP chili had a significant impact on plant height and chili leaf production. The interaction between 50 cm × 70 cm planting distance and 2 WAP water spinach planting time had a significant effect on all investigated variables.

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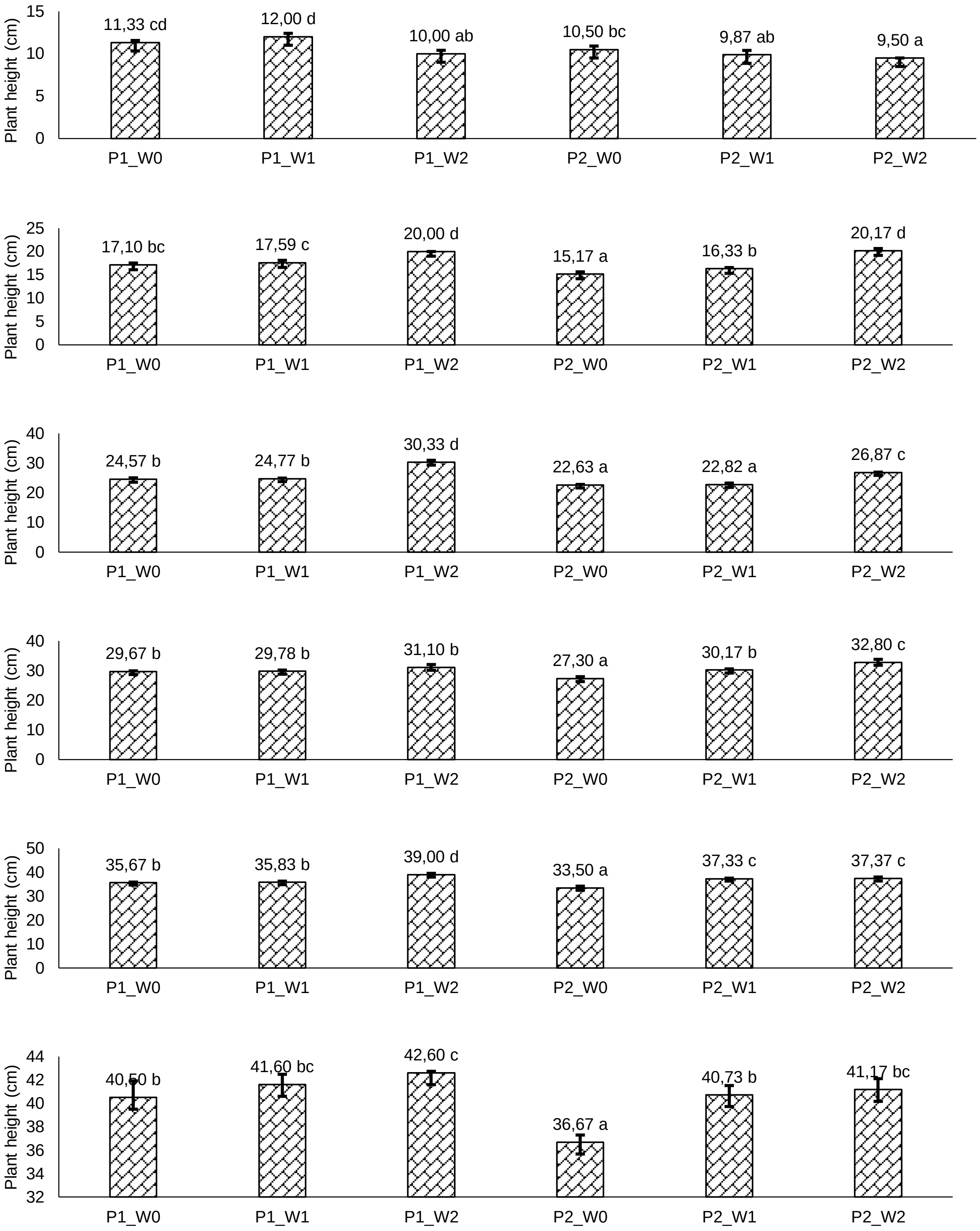

Figure 1 The average height of chili plants at the interaction of planting distance and water spinach planting time at various observation ages. (a) 2 WAP, (b) 4 WAP, (c) 6 WAP, (d) 8 WAP, (e) 10 WAP, (f) 12 WAP. P1: chili planting distance 50 cm x 70 cm, P2: chili planting distance 50 cm x 50 cm, W0: water spinach planting time is the same as chili, W1: water spinach planting time 1 WAP chili, W2: water spinach planting time 2 WAP chili. Numbers with the same letter in the same column did not differ significantly at the 5% DMRT level. The data were presented with the average standard deviation (±) of triplicates.

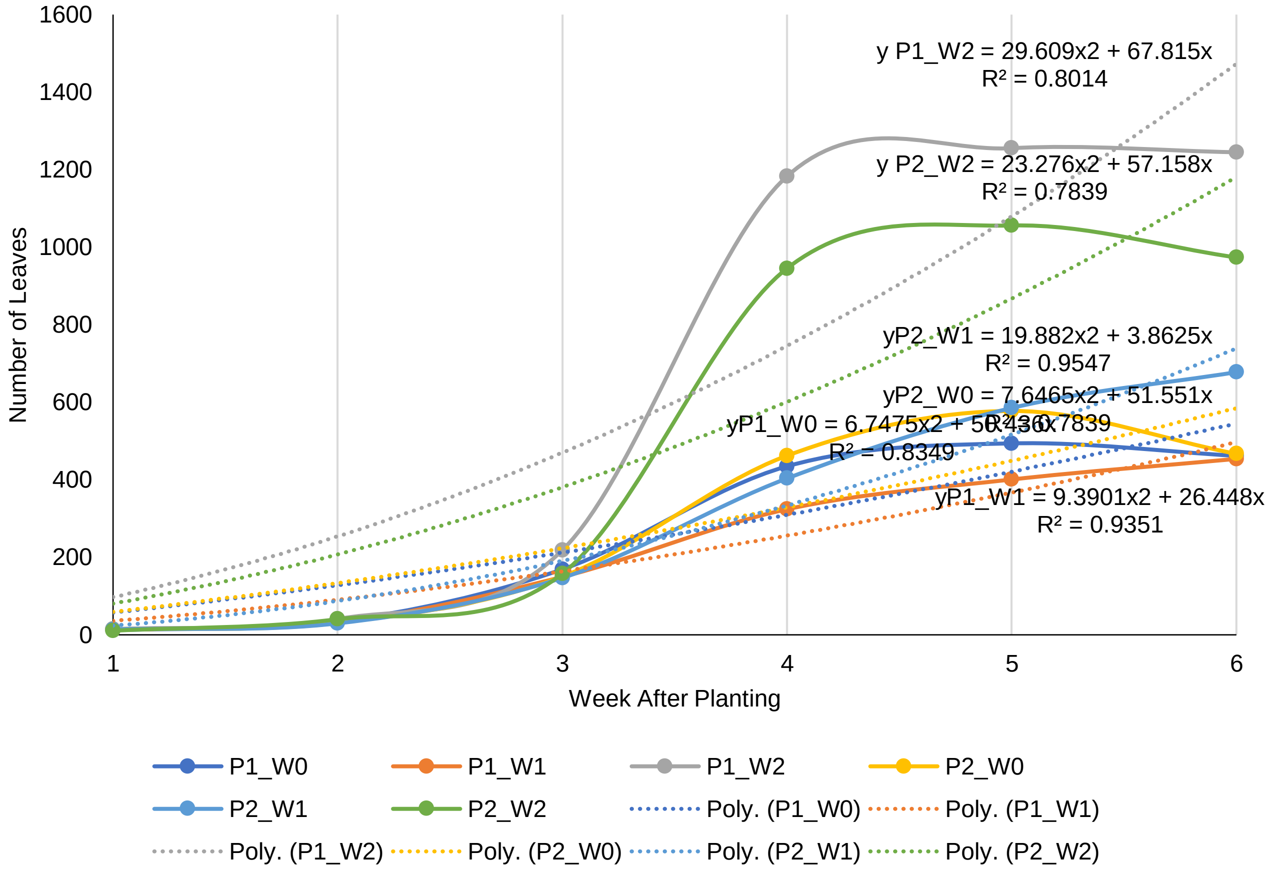

Figure 2 The average number of chili leaves in the interaction of planting distance and water spinach planting time at various observation stages. P1: chili planting distance 50 cm × 70 cm, P2: chili planting distance 50 cm × 50 cm, W0: water spinach planting time is the same as chili, W1: water spinach planting time 1 WAP chili, W2: water spinach planting time 2 WAP chili.

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