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Global warming and the phenology of Yard-long Beans (*Vigna unguiculata* subsp. cylindrica (L.) Verdc.)

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Abstract
A phenomenon in which a temperature difference between the present and the past exists is called Global Warming. Today's temperature is relatively higher than before. This temperature change causes climate change. Climate change due to global warming has caused changes in various areas of life, including plants. One of the plants' most influential physiological processes is the phenology of flower patterns. Studies on the effects of climate change caused by global warming on organisms can be represented by altitude gradients. This study aimed to determine the effect of altitude on the phenology of flower development in Yard long beans (*Vigna unguiculata* subsp. Cylindrica (L.) Verdc.). The parameters observed were the vegetative and phenology of plant development, namely the flowering age (Scale N days after planting), the number of flowers per plant, and flower size. The research was conducted in six places with different altitudes, ± 50 masl, ± 200 masl, ± 400 masl, ±600 masl, ± 800 masl, and ±1,000 masl. The research period lasted for three months. The research was conducted using the survey method. The independent variable used was the difference in elevation gradient, while the dependent variable was the cultivation pattern of yard-long beans. The sampling technique is purposive sampling. The data obtained were analyzed using One-Way analysis of variance (ANOVA) and regression correlation analysis. The analysis showed that altitude affected flowering time, number of flowers, and flower size. Yard-long beans grow and develop optimally at 50-400 meters above sea level.

Keywords: Flowering Patterns, Global Warming, phenology, Yard-long Beans

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INTRODUCTION

The average temperature of the earth's atmosphere, oceans, and land is increasing as increased emissions of greenhouse gases cause the greenhouse effect, thus solar energy is trapped in the earth's atmosphere. This condition is often called global warming (Triani, 2008). Global warming changes various aspects of life, such as plants' morphology and physiological processes (Alexiadis, 2007). Plant physiology affected by global warming is changes in phenology, including budding and flowering. Flowering phenology includes changes in flower size, flowering time, and daily bloom time (Visser & Both, 2005).

In response to climate change, changes in floral phenology have occurred in various flowering plants worldwide. These changes correlate well with temperature changes. Based on this, Parmesan & Yohe (2003) found that changes in floral patterns indicate climate change or increased temperature on plant physiological processes, or it can be said to indicate the negative impact of climate change on agricultural plant life systems.

Phenology is defined as the seasonal activity of an organism (Suhud & Saleh, 2007). Phenological changes that occur is complicated to observe if it does not consider the main factors of the changing environment. Phenological changes must be linked to other environmental factors that are changing.

Global warming can be represented through an altitude gradient above sea level, reflected in increased temperature, increased carbon dioxide (CO_2) levels, and increased light intensity with each decrease in altitude. Temperature, CO_2, and light intensity limit plant survival, especially in the physiological metabolism process. The main factor affecting metabolism, especially anabolism, is the composition of atmospheric carbon dioxide. Abundant CO_2 strongly supports agricultural plant life, primarily by increasing the rate of photosynthesis, thus favoring growth and development at the growth and reproduction stages (Gardner et al., 1991).

Based on the supporting theories above, the altitude gradient can be utilized to study the impact of climate change on the flowering patterns of crops. This statement is supported by previous researchers who used altitudinal gradients to represent climate change (Widhiono et al., 2017). Global warming is thought to cause changes in phenology or adjustments in the timing of seasonal activities, such as flowering time in crops (Walther et al., 2002). The flowering process is essential for plants to maintain the sustainability of a species (Parmesan & Yohe, 2003).

Vigna unguiculata subsp. Cylindrical (L.) Verdc. Known locally as yard-long bean, is one of the flowering plants expected to be affected by global warming. Yard long beans are a group of vegetables that many people like processed vegetables, and fresh vegetables from both villages and cities are savory, crunchy, and delicious (Haryanto et al., 2008).

Yard-long beans belong to the Fabaceae family, which is characterized by what is known as pods. It is a group of C3 plants well adapted to high atmospheric carbon dioxide conditions. Long beans can grow in lowlands as well as highlands. Their adaptability to the growing environment is quite extensive. Yard-long beans grow and produce well from lowlands to highlands up to 1200 m above sea level. In areas below 800 m above sea level, the first harvest can be earlier than in highlands, around 85 HST. On the other hand, in addition to a relatively long harvest season, yard-long cultivation in the highlands also has lower production levels and productivity than in the lowlands (Arsyad, 2007).

Based on these facts, it is necessary to investigate the flowering pattern of yard-long beans at different altitudes to make further predictions on the effects of climate change on the phenology of *Vigna unguiculate* subsp. Cylindrical in the future or determine the optimal altitude for yard-long bean cultivation and knowing the impact of increasing global warming on yard-long beans.

METHOD

This research employed a survey method with two sampling techniques: Purposive and Scan sampling techniques. Purposive sampling is a sampling technique based on specific criteria and objectives while scanning sampling is a direct behavioral observation of an individual at a specific interval (Martin & Bateson, 1993). The research variables consisted of independent and dependent variables. The independent variable was the difference in elevation gradient, while the dependent variable was the cultivation pattern of yard-long beans. The parameters observed were the phenology of plant development, namely the age of flowering (Scale N days after planting), the number of flowers per plant, and flower size. The research was conducted in six places with different altitudes, namely Jambusari Village (Jeruk Legi, Cilacap) ± 50 m asl, Gunung Tugel (Banyumas) ± 200 m asl, Limpakuwus I Village (Banyumas) ± 400 m asl, Limpakuwus II Village (Banyumas) ± 600 m asl, Serang I Village (Purbalingga) ± 800 m asl, and Serang II Village (Purbalingga) ± 1,000 m asl, the research period lasted for three months.

The impact of global warming was observed by observing yard-long bean's vegetative and generative growth. The vegetative growth of yard-long beans was observed from planting seedlings until the first flower bud appeared. Vegetative parameters observed included plant height, number of branches, and number of leaves. At the same time, generative observations started from the appearance of the first flower bud (scale of nth day after planting). Observations were made by recording the time of the first appearance of long bean flower buds, measuring the flower crown, which is divided into a flag (vexillum), wing (alae), and keel (carina) using a beggar, and counting the number of flowers that appear on yard long bean plants.

The obtained data were further analyzed by using One-Way ANOVA and further tests with the Least Significant Difference test. ANOVA was used to determine the average differences in flower emergence time, number of flowers, flower size, number of leaves, plant height, and number of branches at different altitudes (50 m above sea level; 200 m above sea level; 400 m above sea level; 600 m above sea level; 800 m above sea level; and 1000 m above sea level) And regression tests to determine whether there is a relationship between altitude and the flowering pattern of yard-long beans using the help of SPSS software.

RESULTS AND DISCUSSION

Environmental factors such as air temperature, light intensity, humidity, and soil pH had different characteristics at each altitude (Table 1). The measurements of solar irradiation and air temperature at the research site showed a decrease along with the rise in sea level and the increase in humidity. Purwantara (2015) stated that air temperature drops by 0.6^{o}C every 100 meters above sea level. This statement is called the expected rate of temperature decrease because it is averaged across all latitudes and over time. According to Alam (2014), light intensity strongly influences air temperature as a heat source and wind speed to disperse hot air.

Table 1. Average Environmental Conditions at Six Altitudes

Environmental Conditions		Altitude (masl)					
		50	**200**	**400**	**600**	**800**	**1000**
Temperature (^{o}C)	Maks	34,00	32,00	29,00	28,00	26,00	20,25
	Min	24,00	21,00	19,00	18,25	17,25	16,00
Light Intensity (Lux)	Maks	13595	12100	10320	9181,5	8599,5	8159,75
	Min	3860,75	3504,5	2140,75	1675,75	1359,25	1119,5
Humidity (%)	Maks	63,5	70,75	74,00	76,75	84,00	96,00
	Min	58,00	67,75	70,25	74,00	80,00	90,00
pH		6,95	7,00	7,00	7,00	7,00	6,95

Light intensity is highest at 50 masl compared to other altitudes (Table 1). These high light intensity conditions result in high air temperature and low humidity. With increasing altitude, temperature and light intensity decreased, but humidity increased. Altitude above sea level did not affect the relative pH value at the study site. Differences in environmental factors caused by differences in altitude affect plants' vegetative and reproductive growth. This statement follows the statement of Wijayanto and Nurunnajah (2012) that changes in altitude had a significant effect on plant growth because they were related to temperature, light intensity, and optimal plant moisture. Light intensity, temperature, and humidity limit plant growth were related to metabolic processes. According to Richmond (2003), light is the main requirement of phototropic organisms that use light as an energy source that affects plant growth, reproduction, and yield through photosynthesis.

Yard-long beans are optimally cultivated at medium and low altitudes but are less suitable for highlands (Rinaldi et al., 2022). According to Anwar (2013), the optimal temperature for yard-long bean growth is 28-32 ^{o}C with a tolerance of up to 18 ^{o}C with the risk of stunted growth. Besides that, Yard-long beans are a temperate day crop that requires irradiation of at least 8 hours per day (Utami, 2016).

Vegetative Growth of Yard-Long Bean

Vegetative growth parameters measured in this study were plant height, number of leaves, and number of branches. Plant height is one of the parameters to determine the vegetative growth of a plant. Plants continue to grow, indicating that the plant has experienced cell division and elongation. Environmental factors strongly influence plant growth.

Table 2. Average Vegetative Growth Data of Yard-long Bean at 35 Days After Planting (DAP)

Altitude (masl)	Plant height (cm)	Number of Branches	Number of leaves (Blade)
50	98,75[c]	212,00[b]	439,00[bc]
200	143,00[d]	199,00[b]	544,00[bc]
400	143,75[d]	356,00[c]	723,00[c]
600	76,25[bc]	327,00[c]	630,00[c]
800	62,00[ab]	115,00[a]	190,00[a]
1000	28,75[a]	90,00[a]	245,00[a]

Description: Numbers followed by different letters in the same column indicate significant differences.

Yard-long bean plants aged 35 Days After Planting (DAP) showed that altitudes of 200 and 400 m asl had better height growth, and both had no significant differences but were different from other altitudes (Table 2). The yard-long bean is a tropical plant, therefore its growth is optimal at monthly temperatures between 20-35 ^{o}C (Pitojo, 2006). Microclimate characters at altitudes 200 and 400 meters above sea level have light intensity, temperature, and humidity suitable for growing yard-long beans to produce optimum height. Yard-long beans at 35 DAP at 1000 and 800 masl altitudes showed slower growth than plants grown at lower altitudes. Environmental temperature conditions at these altitudes were below the optimum temperature for yard-long beans, thus inhibiting their growth. The result agreed with previous studies that there was a higher increase in plant height under high light intensity (Kim *et* al., 2015).

Other vegetative parameters, namely the number of branches and leaves, showed that the highest number of yard-long bean branches at 35 daps was produced by long beans grown 400 meters above sea level and 600 meters above sea level. The lowest number of branches is at an altitude of 800 and 1000 meters above sea level. Meanwhile, 35 DAP broad beans grown at 400 and 600 meters above sea level produce the highest number of leaves. The lowest number of leaves was 800 and 1000 meters above sea level (Table 2).

Generative Development of Yard Long Bean

Generative development parameters observed in this study were the time of first flower bud appearance, number of flowers, and crown size. Yard-long bean plants at an altitude of 50 meters above sea level (masl) produced flower buds at the age of 26 days after planting (DAP), followed by an altitude of 200 and 400 masl buds appeared 28 days after planting, 600 msl at 30 DAP, an altitude of 800 masl at 46 days after planting, and an altitude of 1000 masl at 49 days after planting.

Table 3. Average Generative growth of Yard long beans

Altitude (m.a.s.l)	Bud's appearance time (days)	Number of Flowers	Flower Size (cm)		
			Vexillum	*Ala*	*Carina*
50	26[a]	29[b]	2.825[bc]	1.45[ab]	1.35[ab]
200	28[b]	34[b]	3.075[c]	1.6[b]	1.5[c]
400	28[b]	38[b]	2.95[bc]	1.525[b]	1.425[bc]
600	30[c]	19[a]	2.675[ab]	1.4[a]	1.3[a]
800	46[d]	9[a]	2.625[ab]	1.375[a]	1.275[a]
1000	49[e]	4.75[a]	2.50[a]	1.35[a]	1.25[a]

Description: Numbers followed by different letters in the same column indicate significant differences.

Yard-long bean plants at 50, 200, and 400 m asl produced the highest average number of flowers compared to other altitudes (Table 3). The difference in the number of flowers was influenced by intrinsic factors and extrinsic factors such as temperature, light, and humidity (Hew & Yong, 2004). Yard-long beans that grew in locations with monthly temperatures of 20-35 ^{o}C can grow and develop optimally, including in flower formation. The growth and development of yard-long beans are less optimal at lower temperatures than at high. The statement indicated the time of first flower appearance, number of flowers, and flower size at 800 and 1000 m asl.

Light, humidity, and temperature support optimal plant growth, and good growth impacts the flowering process (Hew & Yong, 2004). Differences in altitude with different microclimate characteristics of temperature, light, and humidity resulted in differences in flower emergence time. Kramer and Kozlowski (1971) stated that flower initiation is influenced by climate. An increased air temperature can result in an earlier flowering process (Menzel et al., 2006). In addition to temperature, flower initiation is influenced by sunlight intensity. Flowering may be reduced or delayed as irradiance is reduced (Rezazadeh et al., 2018). This statement aligns with the observed yard-long beans, where flowering occurs faster in plants grown in locations with higher temperatures and light intensity. Air humidity that is too low and too high will inhibit plant growth and flowering (Kramer & Kozlowski, 1979).

Yard-long flowers include compound butterfly-shaped flowers (papilion). The structure of the papilion flower is unique in that the corolla resembles a butterfly. The development of long bean flower buds begins with the appearance of flower buds in the axils of the primary leaves or branches. The stalks on the flower buds extend until the buds enlarge and differentiate into full flowers. The flower crown consists of 5 petals, namely two attached crown leaves at the bottom called the keel or carina, and at the top, there is one of the giant crown leaves called the flag or vexillum. Between the two parts, two leaves of the crown to the side, one on the right and one on the left, called wings or ala.

The ANOVA results showed that altitude, air temperature, light intensity, and air humidity had a significant effect on flower size, both vexillum ($p>0.012$), carina ($p>0.015$), and ala ($p>0.015$). Flowers of long bean plants at low and medium altitudes had larger flower sizes than those at higher altitudes (table 3). Flowering was strongly influenced by light intensity and photoperiod. Flowering was strongly influenced by light intensity and irradiation. According to Stirling et al. (2002), photoperiod affected the reproductive process by forming flowers, fruits, and seeds. Plant growth differences also occured due to differences in sunlight intensity (Raharjeng, 2015). Flower size in highland locations with low light intensity resulted in smaller flower sizes than those planted in locations with higher light intensity.

CONCLUSION

The impact of Global Warming on the flowering pattern of yard-long bean flowers had not shown a real negative impact because of the character of yard-long beans, whose growth and development are optimal in the temperature range of 20-35 ^{o}C. The average temperature at the research location was still in that temperature range. The altitude of 50-400 m above sea level was optimal for the growth and development of yard-long beans by producing the most significant number of flowers and the largest size.

Limitations and Future Direction

Further research to see the impact of global warming on the phenology of long bean plants can be held in different seasons, such as the rainy and dry seasons so that it has comparative data. To see the impact of global warming on the phenology of other plants can be done on plants with optimal growth characteristics at low temperatures.

Declarations

F.B.R. is a significant manuscript author, and E.S. and T.H. are co-authors. F.B.R. designed the research and collected and analyzed the data. F.B.R., E.S., and T.H. wrote, revised, and approved the manuscript. The authors state there is no conflict of interest.

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