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Research Article
Growth and Yield of Job's Tears (*Coix lacryma-jobi* L.) Response to Different Types of Oldeman Climate Classification and Row Spacing in West Java Indonesia

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Abstract
Background: Job's tears (*Coix lacryma-jobi* L.) is one of potential staple crop to improve food security as alternative or substitute to rice. Productivity of job's tears need to be developed and improved through the adjustment of the environment and cultivation techniques. Micro climate and crop row spacing in job's tears cultivation has not been widely studied. There was a need to know ideal micro climate and crop spacing to growth and yield of job's tears. The results of this study are very important in agronomic engineering to improve productivity of job's tears. **Materials and Methods:** This experiment used one *Coix* cultivar, which was obtained from the West Java Indonesia that has the characteristics of high yield and a shorter life span. Three types of Oldeman climate and three row spacing were selected and designed to investigate the interactive effects of the types of climate and row spacing on its growth and yield. The experimental design was split plot experimental design with three types of Oldeman climate classification (C_2, C_3 and D_3) used as the whole plot and three types of row spacing (50, 75 and 100 cm) were used as the split plot and three replications. Several agronomic characteristics of *Coix* such as crop height, crop biomass, productive tiller number, panicles number, leaf area index, shoot-root ratio, 100-grain yield and harvest index were recorded. **Results:** This study showed significantly interactive effects of climate type and row spacing on panicles number, leaf area index and shoot root ratio. The results also showed non interactive effects of climate type and row spacing on height, biomass, productive tiller numbers, 100-grain weight, grain weight per crop, grain weight per m^2 and harvest index. However, the different types of climate and row spacing showed significantly independent effects on these parameters but non significantly independent effects on 100-grain weight. **Conclusion:** Based on the results, it was concluded that climate type and row spacing had significantly interactive effects on the growth and yield of *Coix*.

Key words: Climate type, row spacing, Job's tear, growth, yield

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Indonesia faces food insufficiency and food insecurity brought about by most especially the burgeoning population, levelling off-yield, soil fertility decline and climate change. Rice is a staple crop in Indonesia that has a heavy socio-economic pressure so that it is the valid reason to be ready to search, prepare and grow other staple crops, which are equivalent to existing staple crop (rice). Job's tears is one of potential staple crops for alternative or substitute to rice. It is brought into the limelight as a very promising additional food source[1]. Job's tears is a new staple crop in Southeast Asia and is used as a cereal food in the same way as rice. It is also claimed to have medicinal properties and is also used as source of body-enhancing materials[2]. As food diversification is promoted, demand for non-rice food will increase. This increase in demand will stimulate farmers to expand the production of non-rice foods. Job's tear can be processed as food, therefore, a food diversification programme could contribute to the development of job's tear farming and processing[3].

Job's tears *(Coix lacryma-jobi* L.) is a broad-leaved, grain-bearing tropical plant of the family Poaceae. It is native to Southeast Asia but is planted elsewhere in low land or high land as an annual weed crop[4]. It is considered a nutritious health cereal in Asian countries such as China, Japan, Philippines, Burma, Thailand, Brazil and India[5]. Job's tears seed (per 100 g) is reported to contain 380 calories, 11.2 g H_2O, 15.4 protein, 6.2 g fat, 65.3 g total carbohydrate, 0.8 g fiber, 1.9 g ash, 25 mg Ca, 435 mg P, 5.0 mg Fe, 0.28 mg thiamine, 0.19 mg riboflavin, 4.3 mg niacin and 0 mg ascorbic acid[4]. The root and seed of *Coix* are very versatile and they can also be used as herbal medicines[6]. Food scientists have found that job's tears are a rich source of photochemical, that has functions such as anti-tumor, hypoglycemic, antihypertensive, anti-inflammatory[7], anti-virus pharmacological activity and detoxifying agent[8-10]. Medicine scientists take job's tears for hay fever, high cholesterol, cancer, obesity and respiratory tract infections[6,11]. Job's tears cultivation is easy and the plants start quickly from seed. Yields of job's tears vary as to strains cultivated in different countries: Yield of unhusked grains in Philippine islands is about 3.5 t ha^{-1} and in Sri Lanka is 2.1 t ha^{-1} [4].

Crops yield response to different row spacings has varied with variety and environmental influence. Crops row spacing is an agronomic management strategy used by producers to optimize the husbandry of the soil and plant ecosystem from sowing to harvest with the goal of bolstering the production of crops. Crop row spacing influences canopy architecture, which is a distinguishing characteristic that affects the utilization of light, water and nutrients[12]. Appropriate plant density is a key for gainful production of crops in various environments including the hot-humid tropical environments[13,14]. Row and plant spacing under different soil and climatic conditions indicated higher yield and yield components for high planting densities than for low planting densities. Stem length, biomass, pod numbers per plant and proportion of unfilled pods increased as population increased. In other instances, however, as population increased, the number of branches per plant, yield per plant, pod and seed number per plant and seed weight per plant decreased. Population or row spacing also influenced lodging, weed resurgence and N fixation, weed resurgence increased as row spacing increased[15-17]. Proximity factors such as row spacing change the spatial distribution of crop plants and alters the intensity of crop weed competition. Narrow row spacing is likely to facilitate crop plant with greater competitive ability than weeds, compared to wide row spacing[18]. Research services, reinforced the fact that increasing row spacing decreases cereal yield, with the greatest effect when the yield potential is highest. They also found that increasing row spacing reduces tiller numbers, crop biomass, the number of heads and overall water use efficiency and that there is a rotational effect, with the yield penalty for wider row spacing greater in wheat following a pulse or canola because of the higher yield potential of those crops[19,20].

Weather condition (rainfall and temperature) will affect the growth, development and yield of crop plants. The weather related effects on crop growth and crop yield depend on other agronomic factors, such as, fertilizer use, plant density, soil type and soil condition. Temperature and rainfall are the two most important aspects in agriculture. One of the major weather conditions that have an impact on crop yield is the amount of rainfall received during growing season. Temperature has been an important climatic factor determining the cropping pattern and quality of products. The seasonal and spatial variation of temperature and rainfall, to a great extent, regulates the agricultural activities. As most of the farmers have to depend on suitable weather conditions to commence their farm activity, seasonal variation in climate has remarkable implication in the sustainability in agriculture[21]. Temperature will affect the physiological processes necessary for crop growth and development of crops and ultimately crop yields. Temperature effects enzyme system in crops so that most crop species sustained in cardinal temperatures that have a relatively narrow range. Productivity of crop species falls markedly at high or low temperatures. Acute effects of high temperature are most striking when heat stress occurs during anthesis. Heat stress at anthesis prevents anther dehiscence and pollen shed, to reduce pollination and grain numbers. Maximum and minimum temperatures adversely affect seedling establishment, accelerate early vegetative development, reduce canopy cover, tillering, spike size and yield[22,23].

Rainfall is the most important climatic factor influencing the growth characteristics of crops. Rainfall provides the water that serves as a medium through which nutrients are transported for crop development. In view of this significant role, clearly, inadequate water supply has adverse effects on efficient crop growth, resulting in low productivity. In many parts of the world rainfall amount affect water availability in the soil, crop type, growth patterns of crops and yield outcome of crops. The decrease in seasonal rainfall from the long-term average generally translates into a decrease in food production[24,25]. Rainfall is a factor behind most of the adversities of the agricultural sector. Rainfall especially affecting the growth and production of the plants. Low rainfall has been attributed to be the cause of large drops in production yield[26].

Row spacing and weather will inevitably have an impact on growth of crop and grain yield. Therefore it will be very important to study the impact of row spacing and weather on the yield of the job's tears. Variations in row spacing and weather are expected to influence the pattern of *Coix*'s growth and development, very few reports have examined this issue in detail. The objective of this study was to quantify the impact of row spacing and weather on the growth, development, yield and agronomic performance of job's tears. This study presented the growth and yield of job's tears for responses to different row spacing and weather in West Java Indonesia.

MATERIALS AND METHODS

In this experiment one *Coix* (*Coix lacryma-jobi* L.) cultivar was used which was obtained from the West Java region that has the characteristics of high yield and shorter life span. The screened *Coix* grains were hydro-primed for 12 h and incubated for 6 h before sowing. Pre-germinated seeds were sown on the medium plates (mixture of fine sand and sawdust, the ratio is 2:1). After four days, the shootings were transferred to the experiment field.

The field experiment were conducted during February to June 2016 at the three locations in West Java (Lembang Bandung, Sukasari and Rancakalong Sumedang) following the Split Plot Experiment Design (SPED) with three replications. Three types of Oldeman climate classification (C_2, C_3 and D_3) were the whole plot (factor A treatments) and three types of row spacing (50, 75 and 100 cm) were used as the split plot (factor B treatments). The intra spacings (distance between plants in row spacing) were 50 cm. The C_2 is six consecutive of wet months and three consecutive of dry months. The C_3 is six consecutive of wet months and four consecutive of dry months. The D_3 is four consecutive of wet months and four consecutive of dry months. Wet months are when rainfall is more than 200 mm/month and dry months are when rainfall is less than 100 mm/month. There were 27 experimental plots and the size of each experimental plot was 4×2 m. The plots were regularly hand-weeded until canopy was closed to prevent weed damage. Insecticides were used to prevent insect damage. All other agronomic practices were used according to local recommendations and kept normal and uniform for all the treatments.

Crop height, crop biomass, productive tiller number, panicles number, leaf area index, shoot-root ratio, 100-grain weight, grain weight per crop, grain weight per m^2 and harvest index were recorded in detail. The data were statistically analyzed according to the method appropriate for SPED using software SPSS version 16. The differences among treatment means were compared using Least Significant Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Climatic data of the experimental area: Meteorological data for the *Coix* growing seasons at three experiment area are shown in Table 1. During the vegetative and generative period (from February to June) in 2016, there was total precipitation of 289.5 and 284.2 mm, average temperature of 20.6 and 19.7°C and an average humidity of 61.0 and 66.1%. In general, climate and weather conditions in the three study sites were nonproblem for growth of *Coix*. *Coix* is a plant that has a wide adaptation to the environment from the lowlands to highlands.

It was fount that difference of rainfall, temperature and relative humidity could greatly affect yield of *Coix* (Table 1). This indicated that rainfall, temperature and air humidity have a great impact on the growth and development of *Coix*. Results of study indicated that the rainfall, temperature and relative humidity during the growing period of *Coix* significantly influenced its growth and development and eventually the yield. Grain yield was less affected by air temperature. According to Rasul *et al.*[23], climate and weather help to determine cropping systems and yields of individual crops. Likewise, Mahmood *et al.*[24] and Bhandari [27] mentioned that weather (rainfall and temperature) plays a decisive role in crop production and this contributes to 50% variations. Saito *et al.*[20] and Mahmood *et al.*[24] informed that for

Table 1: Data of weather, climate type and *Coix* grain yield in three experiment areas in West Java (Lembang Bandung, Rancakalong and Sukasari Sumedang)

	Climate data				
Experiment areas	Rainfall (mm)	Temperature (°C)	RH (%)	*Types of Oldeman climate classification	*Coix* grain yield (g per crop)
Lembang Bandung	143	22.7	84	C_2 (6 consecutive of wet** months and 3 consecutive of dry** months)	173.88[a]
Rancakalong Sumedang	374	23.1	76	C_3 (6 consecutive of wet** months and 4 consecutive of dry** months)	286.33[b]
Sukasari Sumedang	228	23.2	89	D_3 (4 consecutive of wet** months and 4 consecutive of dry** months)	229.93[a]

*Types of Oldeman climate classification based on climate data for long years (2000-2015), **Wet months when rainfall is more than 200 mm per month and dry months when rainfall is less than 100 mm per month

well-adapted crop varieties, yield and quality can still be affected strongly by weather and by agronomic interventions[28]. Heat and drought during grain filling, availability of nutrients and control of pests highly influence grain quality.

Growth of job's tears: panicles number, leaf area index, shoot root ratio, height, biomass and productive tiller numbers: Analysis of variance showed significantly interactive effects of types of climate and row spacing on panicles number, leaf area index and shoot root ratio of coix (Table 2-4). The types of climate and row spacing affect the panicles number, leaf area index and shoot root ratio. These parameters were significantly higher at wider spacing row and drier climate type. Cox and Cherney[29] noted Leaf Area Index (LAI) and biomass accumulation had linear responses to row spacing. Zibelo *et al.*[30] also showed leaf area index, plant height and number of leaves crop were significantly ($p<0.05$) affected by the main effects of inter-and intra-row spacing. The Leaf Area Index (LAI) and Total Dry Matter (TDM) are influenced by genotypes, climate, soil fertility and plant density.

The results of study showed non interactive effects of types of climate of and row spacing on *Coix* growth parameter (height, biomass and productive tiller numbers). The different types of climate and row spacing showed significant differences on height, biomass and productive tiller numbers of *Coix*. The height and biomass in the three types of climate and three row spacing showed regular changes. It shows that the wet climate has better on height and biomass of *Coix* (Table 5). This fact indicated that there was direct correlation between the crop height, crop biomass and productive tiller numbers and types of climate. It was also found that the wider row spacing has better effect on biomass and productive tiller numbers but not better effect it was on height of *Coix*. It was also found that there was direct correlation between the crop height, crop biomass and productive tiller numbers and row spacing. Increased tiller production under low plant densities (wider row spacing) has been observed previously in grain yield. *Coix* spaced at wider rows had more productive tillers than at narrower row spacing.

Table 2: Effects of types of oldeman n climate and row spacing on panicles number

Types of Oldeman climate	Row spacing		
	50 cm	75 cm	100 cm
C_2	96.00[aA]	83.00[aA]	92.22[aA]
C_3	83.56[aA]	117.67[abB]	103.67[aAB]
D_3	147.56[aA]	163.18[bA]	190.74[bB]

Values followed by lowercase letters and uppercase letters showed non significant difference according to least significant difference test at 5% test level

Table 3: Effects of types of oldeman climate and row spacing on leaf area index

Types of Oldeman climate	Row spacing		
	50 cm	75 cm	100 cm
C_2	2.78[aB]	1.56[aA]	1.38[aA]
C_3	5.50[aA]	5.75[bB]	5.16[bA]
D_3	6.68[aB]	4.77[bB]	3.95[bA]

Values followed by lowercase letters and uppercase letters showed non significant difference according to least significant difference test at 5% test level

Table 4: Effects of types of oldeman climate and row spacing on shoot root ratio

Types of Oldeman climate	Row spacing		
	50 cm	75 cm	100 cm
C_2	3.05[abA]	2.92[aA]	2.88[aA]
C_3	2.15[aA]	5.11[bB]	3.60[aAB]
D_3	4.82[bA]	4.35[abA]	5.79[bA]

Values followed by lowercase letters and uppercase letters show non significant difference according to least significant difference test at 5% test level

Yield of job's tears: 100-grain weight, yield and harvest index: Analysis of variance showed non significantly interactive effects of climate type and row spacing on *Coix* yield parameters (100-grain weight, grain weight per crop, grain weight per m^2 and harvest index). The different types of climate and row spacing showed non significant differences on 100-grain weight of coix. 100-grain weight among different types of climate and row spacing all no reached significant levels. 100-grain weight of climate type C_2 was non significantly different than those of other types of climate (Table 6). Also, 100-grain weight of row spacing 50 cm was non significantly different than those of other row spacing. This fact indicated that types of climate and row spacing have not a correlation with 100-grain weight of coix and genetic characteristics could play an important role in 100-grain weight of *Coix*. The different types of climate and

Table 5: Effects of types of Oldeman climate and row spacing on crop height, crop biomass and productive tiller numbers

Treatments	Crop height (cm)	Crop biomass (g)	Productive tiller numbers
Types of Oldeman climate			
C_2	190.31^c	1668.38^b	275.19^a
C_3	160.40^b	846.23^a	166.99^a
D_3	138.81^a	893.41^a	660.49^b
Row spacing (cm)			
50	176.58^c	1027.52^a	316.82^a
75	160.12^b	1128.97^{ab}	362.90^{ab}
100	152.80^a	1251.53^b	422.95^b

Values followed by lowercase letters show non significant difference according to least significant difference test at 5% test level

Table 6: Effects of types of Oldeman climate and row spacing on 100-grain weight, grain weight per crop, grain weight per m^2 and harvest index

Treatments	100-Grain weight (g)	Grain weight per crop (g)	Grain weight per m^2 (g)	Harvest index
Types of Oldeman climate				
C_2	13.07^a	173.88^a	370^a	0.12^a
C_3	12.79^a	286.33^b	633^b	0.38^c
D_3	12.43^a	229.93^a	529^c	0.26^b
Row spacing (cm)				
50	12.95^a	192.38^a	616^c	0.26^a
75	12.41^a	239.39^{ab}	503^b	0.26^a
100	12.94^a	258.38^b	413^a	0.25^a

Values followed by lowercase letters show non significant difference according to least significant difference test at 5% test level

row spacing showed significant differences on grain weight per crop, grain weight per m^2 and harvest index. This fact showed that correlation between the grain weight per crop, grain weight per m^2 and harvest index and three climate type and row spacing are significant. Grain weight per crop, grain weight per m^2 and harvest index of three climate type showed no regular changes but those of row spacing showed regular changes. It showed that the types of climate and row spacing have a different effect on grain weight per crop, grain weight per m^2 and harvest index (Table 6). This fact indicated that there was direct correlation between the climate type and grain weight per crop, grain weight per m^2 and harvest index. It was also found that the wider row spacing has better effect on grain weight per crop but not better effect on grain weight per m^2 and harvest index. This result also indicated that there was direct correlation between the row spacing and grain weight per crop, grain weight per m^2 and harvest index of coix.

Aradilla[3] noted that *Coix* did not differ significantly on the weight of 1000 grains. This facts indicated that row spacing have not a correlation with 100-grain weight and genetic characteristics could play an important role in 100-grain weight of *Coix*. An increase in the plant density results in increased competition among the plants for growth requirement factors such as adequate space for growth and development of shoots and roots, light, nutrients and moisture and as a result, individual plants show less growth and development. But, despite the reduced growth and development of individual crops, the total grain yield per unit area increases due to increased number of crops per unit area[31].

Moreover, during dry, hot spells, *Coix* plants were severely affected due to less or no available soil moisture. Therefore, to obtain the highest growth and yield, the row spacing of *Coix* should be 100 cm at C_3 climate type, which is in line with the analysis of crop height, crop biomass and grain weight per crop.

CONCLUSION

In conclusion it was found that high rainfall, moderate temperature, low relative humidity and climate type had significantly effects on the growth, development and yield of *Coix*. The combination of type of climate and row spacing showed significantly interactive effects on panicles number, leaf area index and shoot root ratio. These parameters were significantly higher at wider spacing row and drier climate type. The results also showed non interactive effects of climate type and row spacing on height, biomass, productive tiller numbers, 100-grain weight, grain weight per crop, grain weight per m^2 and harvest index. However, the different types of climate and row spacing showed significantly independent effects on these parameters but non significantly independent effects on 100-grain weight. This fact showed that significant correlation between the height, biomass, productive tiller numbers, grain weight per crop, grain weight per m^2, harvest index and three of climate type and row spacing. Therefore, to obtain the highest growth and yield, the row spacing of *Coix* should be 100 cm at C_3 climate type, which is in line with the analysis of crop height, crop biomass and grain weight per crop.

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