NUSANTARA BIOSCIENCE
Vol. 9, No. 3, pp. 243-250
August 2017

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n090302

The effect of growing season on growth rate, pod partitioning, phenology and yield variations of mungbean varieties

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Manuscript received: 18 November 2016. Revision accepted: 7 June 2017.

Abstract. *Pratiwi H, Rahmianna AA. 2016. The effect of growing season on growth rate, pod partitioning, phenology and yield variations of mungbean varieties. Nusantara Bioscience 9: 243-250.* The primary objective of mungbean improvement program is the production of high yielding varieties, which is influenced by physiological trait of variety or genotype and environment. The present research aimed to study the effect of growing season on growth rate, pods partitioning, phenology and yield variations of several mungbean varieties. Field experiments were conducted at Muneng Experimental Station of the Indonesian Legume and Tuber Crops Research Institute (ILETRI), Probolinggo District, East Java, Indonesia during rainy season (October to December 2011), and dry season (May to July 2012). A randomized complete block design was employed in the present study consisted of mungbean varieties as treatments in each growing season, and three replicates. The treatments were superior mungbean varieties, i.e. Vima 1, Sriti, Murai, Kutilang and Fore Belu. The observed variables were plant phenology, plant growth rate, seed yield and yield attributes. The results indicated the growing season affected plant growth rate, pod partitioning, phenology and seed yield and yield components with rainy season influenced more parameters of plant growth rate, crop phenology, seed yield and its components as compared to dry season. Conversely, dry season had more effect on pod partitioning coefficient, total dry biomass rate, and seed size. There was significant interaction effect of genotype by growing season on total dry matter and pod growth rates, days to flowering, days to pod maturity, plant height, seed yield, plant population, pod weight, and 1000-seed weight. Seed yield varied among seasons and varieties with the average seed yield in rainy season was 75 to 119% higher than those in dry season except Fore Belu that had the same yield in both seasons.

Keywords: Growth rate, mungbean varieties, phenology, pod partitioning, season

INTRODUCTION

Mungbean (*Vigna radiata*) is the fifth leading food crops in Indonesia with a high protein content. Mungbean is usually planted in the dry season as the second crop after paddy rice, maize or peanut because of its short duration and drought tolerance. Until recently, 25 superior mungbean varieties had been released by The Indonesian Ministry of Agriculture since 1945 up to 2016. Each of these varieties has specific characteristics despite their high protein content that ranges from 18-28% (Iletri 2016). Efforts to obtain high mungbean yield can be carried out through appropriate selection of superior variety that is suitable to the climate and environmental condition of the growing sites. However, farmers in some regions are still continuously cultivating local varieties because they are not aware of the existence of the above mentioned superior varieties (Badal et al. 2007). Vima 1, Sriti, Murai and Kutilang are superior varieties that are widely distributed and grown in Indonesia (Iletri 2011). These varieties have specific characters and yield potential. Vima 1 variety is a short duration variety with yield potential of 1.76 t ha^{-1}. Sriti and Murai are high yielding varieties with yield potential of 2.45 t and 2.5 t ha^{-1}, respectively. Kutilang variety has large seed size with yield potential of 1.96 t ha^{-1} (Iletri 2012). Despite their high yield potential, the actual yields of these varieties in the farmers' fields are still low. The average mungbean productivity at the national level in 2015 was only 1.18 t ha^{-1} (Central Bureau of Statistic Indonesia 2015) with a large yield variation among production centers. This indicates a significant interaction of genotype by the environment on the mungbean yield (Trustinah 2013). Kuo (1998) reported that mungbean yield per unit area is determined by the characters of variety, environment, and cultivation technology. Meanwhile, Chauhan et al. (2010) revealed that establishment of crop yield could be explained by the capture and management of environmental resources such as solar radiation, soil water, and nutrients for the production of biomass. According to Atwell et al. (1999), the balance between vegetative and reproductive growths is very important in determining the final yield. Vijaylaxmi and Bhattacharya (2006) reported that mungbean seed yield is positively affected by total dry matter production, dry matter production per day, dry matter partitioning per day, and negatively affected by dry matter allocated to pod wall. Mondal et al. (2011) stated that leaf area index contributes to total dry biomass, while number of racemes, flowers, and pods per plant contribute mostly to seed yield. Furthermore, mungbean genotypes with high leaf area, high total dry biomass, and high crop growth rate produce higher seed yield (Mondal et al. 2012).

Plant growth is affected by the interaction of various environment elements on certain temperature range, while plant development is affected by temperature changes (Gordon and Bootsma, 1993). According to Miller et al. (2001), plants need a certain amount of temperature units or *growing degree days* to develop from one to the next growth phase and the different heat requirement of each genotype will cause variation in growth and yield.

The atmospheric temperature change relates to climate change. Unpredictable climate change at many regions in the world generates global climate change, which causes prolonged dry season (El Nino) or rainy season (La Nina). As a result, farmers face difficulties in determining the most appropriate planting schedule (Jennings and Magrath 2009). Unpredictable season changes affect plant phenology and productivity (White et al. 2003; Cleland et al. 2007; Rai 2015). Hence, it is necessary to evaluate mungbean varieties in different growing seasons to obtain the factors that affect the variation of growth and yield and to observe the more potential variety. The objective of this research was to study the effect of growing season on growth rate, pods partitioning, phenology and yield variations of several mungbean varieties.

MATERIALS AND METHODS

Field experiments were conducted at Muneng Experimental Station of the Indonesian Legume and Tuber Crops Research Institute (Iletri), Probolinggo District, East Java Province, Indonesia (7.7°S, 11.2°E, 10 m above sea level) during the rainy season (October to December 2011), and dry season (May to July 2012). Indonesia has two main seasons *i.e.* rainy/wet season and dry season; each lasts for six months. The rainy season starts from the end of October/early November to the end of March/early April, and dry season starts at the end of March/early April and finishes at the end of October/early November. The climate data during the research period was presented in Table 1.

A split plot design was employed in the present study with seasons as the main plots, and mungbean varieties as subplots. The mungbean varieties consisted of five superior varieties, namely Vima 1, Sriti, Murai, Kutilang and Fore Belu. Each variety was grown in a 5 m x 6 m plot size. In each season, the treatments were laid out in a randomized complete block design, and three replications. Vima 1 was originated from the crossing of VC2750A and VC 1973A; Sriti and Kutilang were introduced from Taiwan; Murai was introduced from the Philippines, and Fore Belu was a local variety from Belu, East Nusa Tenggara, Indonesia. The experimental areas were previously grown with corn. Land preparation was done properly to obtain friable soils, free from any debris of previous crops and weeds. The fertilizer used was composite NPKS (250 kg ha^{-1}), applied at planting time. Plant spacing was 40 cm between rows and 10 cm within row. The irrigation was applied once (at 0 days after sowing, DAS) during the rainy season cropping, and four times (at 0, 12, 32, and 45 DAS) during the dry season cropping. Weeding was done twice and pest control was done depending on the incidence of pests and diseases.

Data was collected on Growth Degree Days (GDD), plant phenology, plant growth, seed yield, and yield attributes. The observed plant phenology covered days to 50% flowering and 50% pod maturity. Growth analysis included growth rate and pod partitioning, where the observations were started at 10 DAS in a 10-day interval, and finished at 60 and 70 DAS for rainy and dry seasons, respectively. Growth analysis was done by destructive sampling of all plants in the area of 0.8 m^2 (2 rows, 1 m long) outside the harvesting plot. The plants were separated into roots, stems, leaves, and pods and the corresponding dry weights were recorded after oven drying at 80 °C for 72 hours. At harvesting time, all pods in the plots were harvested. Harvesting time of mungbean varieties in the rainy season was started at 60 DAS for Vima 1, Sriti, Kutilang, Murai varieties except for Fore Belu variety (at 70 DAS). In the dry season, the pod harvesting of Vima 1, Sriti, Kutilang, Murai varieties was started at 70 DAS, and that of Fore Belu variety was at 80 DAS. Vima 1 was harvested once while the other three varieties were harvested three times. The pods were then sun-dried until the seeds reached 10% water content, and unshelled to separate the seeds from the pods prior to weighing. The number of harvested plants in each plot was recorded. The observations were undertaken on plant yield and yield components including 1000 seed weight, number of pods plant^{-1}, pods and seeds weight harvested plot^{-1}.

Growth Degree Days (GDD) is an accumulation of daily temperature minus base temperature of mungbean. Daily GDD were calculated based on Tzudir et al. (2014):

Table 1. Temperature, rainfall, and relative humidity on research site during growing seasons of mungbean

Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Number of rainy days
	Minimum	Maximum	Average			
Rainy season (2011)						
October	23.2	34.7	28.0	55.6	0	0
November	23.1	28.5	25.8	65.8	133	5
December	23.5	29.0	26.2	65.0	122	12
Dry season (2012)						
May	22.6	33.6	27.5	72.8	16	2
June	20.7	33.4	26.3	51.6	22	1
July	20.1	32.9	26.1	51.4	0	0

Source: weather station of Muneng Experimental Station, Probolinggo District, East Java Province, Indonesia

$GDD=[((T_{max}+T_{min})/2)-T_{base}]$

Where,

T_{base}= base temperature below which the crop cannot thrive, T_{base} for mungbean=10 ^{o}C

T_{max}=daily maximum temperature

T_{min}=daily minimum temperature

Plant growth rate is the *gradient* of regression equation between the plant age and plant dry matter (Manshuri 2011). The coefficient of pod partitioning is the ratio of pod growth rate with crop growth rate (Duncan et al. 1978). The collected data were statistically analyzed following the analysis of variance, and the mean differences were assessed by using LSD. The correlation analysis was performed to find out the relation between parameters observed.

RESULTS AND DISCUSSION

Plant growth rate and pod partitioning

Growing season affected leaf and stem growth rate, as well as pod partitioning coefficient, whereas varieties affected only stem growth rate (Table 2). Leaf and stem growth rates were superior in the dry season. Conversely, pod partitioning coefficients were superior in the rainy season. Leaf growth rate in the dry season was 39% higher than that in the rainy season; however, there was no significant variation among varieties. Stem growth rate in the dry season was 163% higher than that in the rainy season and significantly varied among varieties. The highest stem growth rate was observed in Fore Belu and Sriti while the lowest one was observed in Vima 1.

The pod partitioning coefficient in the rainy season was two times higher than that in the dry season. The coefficient was >1 in the rainy season and <1 in the dry season. According to Purnawati and Manshuri (2015), pod partitioning coefficient above 1 indicates that the increase of pod dry weight is higher than the increase of plant dry biomass rate. A higher pod partitioning coefficient indicates that a higher amount of assimilates is distributed to the economic parts of the crop. All varieties possessed the same capability in distributing assimilates to the pods as shown by their non-significantly different pod partitioning coefficients.

There was an interaction effect of growing season and mungbean varieties on total dry biomass, pod growth rate, and plant height (Table 3). Total dry biomass growth rate of all varieties in the dry season was 40-222% higher than those in rainy season except Vima 1, which exhibited the same rate in both seasons. Fore Belu produced the lowest as well as the highest total dry biomass growth rates in the rainy and dry season, respectively. All varieties had 27-92% higher pod growth rate in the rainy season than those in dry season except Fore Belu, which on the contrary, had 32% lower pod growth rate in the rainy season than in dry season. Vima 1 and Fore Belu had the highest and the lowest pod growth rate, respectively. All varieties grew 1.7-2.6 times taller in the rainy season than those in dry season. Fore Belu was the tallest in both seasons, while Vima 1 was the shortest in both seasons (Table 3).

Table 3 shows that Fore Belu had the lowest pod growth rate and the highest plant height in both seasons. This low pod growth rate was due to its dominant vegetative growth especially the plant height. Conversely, Vima 1 variety was a short plant but had a dominant pod growth rate. These differences are presumably due to the different genetic background of the two varieties. Fore Belu had a semi-determinate growth type (Iletri 2012), and therefore the plant is still continuing its vegetative growth when its generative growth has been commenced. Vima 1, on the other hand, has a determinate growth type (Iletri 2012) where its vegetative growth has stopped when the plant enters the reproductive phase. The semi-determinate trait enables the pods to grow optimally as “sink” while the leaves and stems as “source” continuously grow (Atwell 1999). In other words, there is a competition between pods and leaves + stems in using the assimilate. The other reason for this slow pod growth rate of Fore Belu could be due to shorter pod formation period as a result of the slow/late initiation of the flowering period (Vijaylaxmi and Bhattacharya 2006).

Table 2. Leaves growth rate, stem growth rate, and pod partitioning coefficient of mungbean varieties in different growing seasons.

Treatment	**Leaf growth rate (g m^{-2} day^{-1})**	**Stem growth rate (g m^{-2} day^{-1})**	**Coefficient of pod partitioning**
Growing season			
Rainy	1.68 b	1.14 b	1.60 a
Dry	2.33 a	3.00 a	0.82 b
Varieties			
Vima 1	1.76 a	1.69 b	1.35 a
Sriti	2.34 a	2.25 a	1.17 a
Murai	1.88 a	2.01 ab	1.24 a
Kutilang	1.75 a	2.05 ab	1.27 a
Fore Belu	2.29 a	2.35 a	1.02 a

Note: Values in the same treatment that followed by the same letter (s) were not significantly different at LSD 5%

Table 3. Pod and total dry biomass growth rate, plant height of mungbean varieties on different growing seasons

Growing season	**Varieties**				
	Vima 1	**Sriti**	**Murai**	**Kutilang**	**Fore Belu**
Total dry biomass growth rate (g m^{-2} day^{-1})					
Rainy	6.48 c	6.58 c	6.26 c	5.73 c	2.89 d
Dry	7.11 bc	9.22 a	8.24 ab	8.10 ab	9.30 a
Pod growth rate (g m^{-2} day^{-1})					
Rainy	11.81 a	9.76 b	9.87 b	9.38 bc	3.98 f
Dry	6.15 de	7.65 cd	7.31 de	7.09 de	5.83 e
Plant height at harvest (cm)					
Rainy	75.55 cd	103.75 b	83.20 c	85.60 c	170.20 a
Dry	45.30 f	48.35 f	55.90 ef	51.75 f	64.35 de

Note: Values in one variable followed by the same letter (s) were not significantly different at LSD 5%

Total dry biomass production of all varieties gradually increased in rainy season (Fig 1A), but it then sharply increased in dry season (Fig 1B). The dry season crops are supposed to be harvested earlier than the crops grown in rainy season. The figures, however, showed that rainy season crops were harvested 10 days earlier than those of dry season ones. This might have happened because all varieties were attacked by the bean flower thrips (*Megalurothrips usitatus*) during the vegetative phase in the dry season. The infected plants then successfully recovered their growth and established new and healthy leaves after being sprayed with chemical insecticides. As a result, the plants in the dry season had a longer maturity than that in the rainy season. In the rainy season, total dry biomass was low at early growth (10-20 DAS), which then increased rapidly at the onset of the reproductive stage (20-30 DAS). The total dry biomass of the plants grown in the rainy season was constant at 30-40 DAS, and then rapidly increased after 50 DAS following the pod filling period (Figure 1 A). The longer duration of Fore Belu made the dry biomass of the variety observed until 70 DAS. However, the total dry biomass of this variety decreased sharply in the last observation as many leaves dropped due to senescence. In the dry season, total dry biomass rapidly increased from 20 until 60 DAS (Figure 1 B). This was in accordance to Mondal et al. (2012), who stated that plant dry biomass increased rapidly after the reproductive stage. Total dry biomass of Sriti and Fore Belu tended to increase after 60 DAS, which resulted in a higher total dry biomass growth rate than other varieties (Figure 1B).

Figure 2A and 2B showed pod dry weight at 40-70 DAS in rainy and dry seasons, respectively. The figures indicated that the observation on pod weight was commenced at 40 DAS. Pod weight in 40 DAS was very low i.e., below 5 g m^{-2} and then increased until reached point above 100 g m^{-2} in the last observation. Pods yield in the rainy season was higher than that in the dry season. In the rainy season, Vima 1, Sriti, Murai and Kutilang had the same pods weight, while Fore Belu had the lowest due to its dominant vegetative growth (Figure 2A). In the dry season, pod dry weights among five varieties were slightly different, and Fore Belu had the lowest pod weight. Water shortage in dry season inhibited pod formation and resulted lower pod dry weight as compared to that in the rainy season.

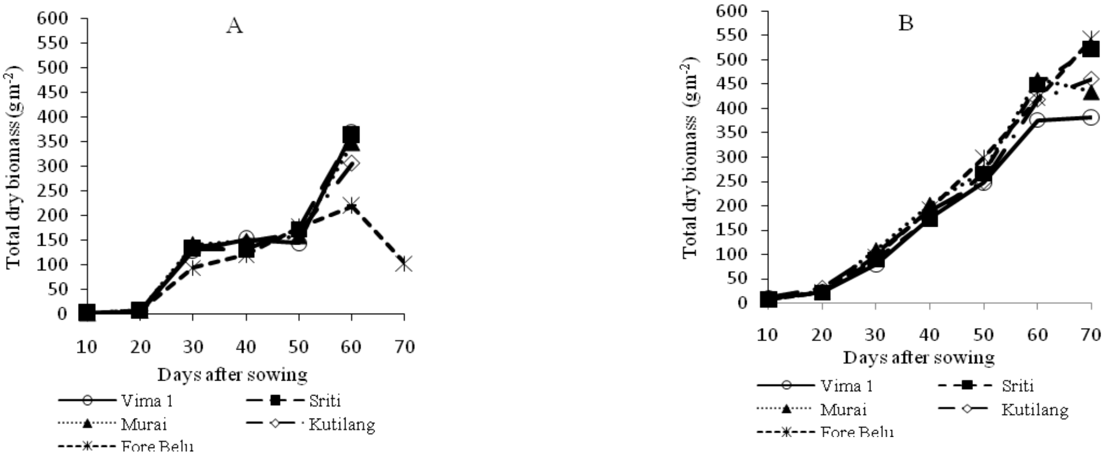

Figure 1. Total dry biomass on 10, 20, 30, 40, 50, 60 and 70 days after sowing in rainy season (A) and dry season (B)

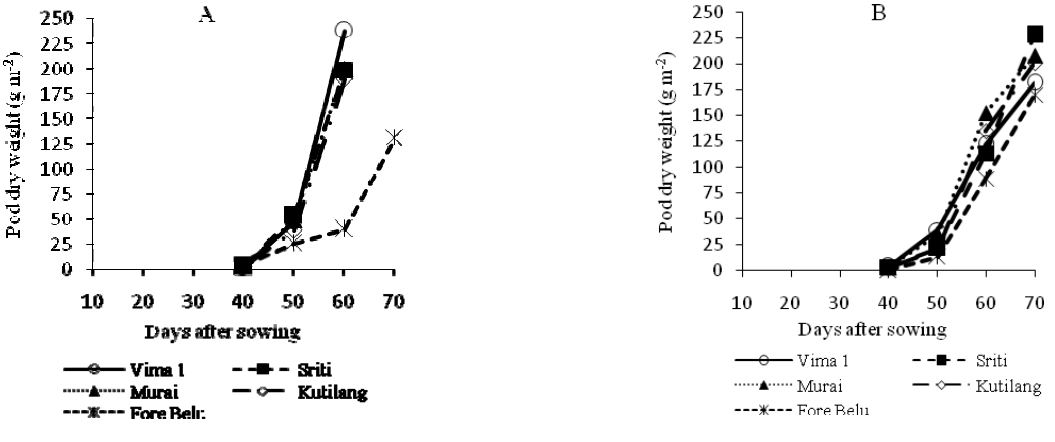

Figure 2. Pod dry weight on 10, 20, 30, 40, 50, 60, and 70 days after sowing in rainy season (A), and dry season (B)

Plant phenology

The present study results revealed significant interaction effect of season and variety on days to flowering, GDD of flowering, days to mature, and GDD of maturing (Table 4). Across seasons, the longest flowering date was observed in Fore Belu *i.e.* 38 DAS, while the shortest was observed in Vima 1 grown in dry season *i.e.* 34 DAS. The same patterns were observed on GDD of flowering, maturing date, and GDD of maturing. The data pointed out that the longer the flowering date, the longer was the maturing date. For example, Vima 1 and Kutilang had the shortest flowering and maturing dates, while Fore Belu had the longest flowering and maturing dates (Table 4). The average maturing dates for Vima 1, Sriti, Murai, Kutilang, and Fore Belu across the production center areas in Indonesia were 53 days, 60-65 days, 63 days, 60-67 days, 60 to 67 days, respectively (Ministry of Agriculture Republic of Indonesia 2005; Iletri 2012). In this research, all mungbean varieties had a maturing date earlier than those mentioned in their varietal descriptions. In addition, the flowering and maturing dates of all varieties in dry season were shorter than those in rainy season. One likely reason for this finding was the air temperature differences between the two seasons. Menzel et al. (2006) mentioned that the rising of temperature accelerates flowering and maturing dates and the effects varies between the plants. As reported in Table 1 that the mean air temperatures during the experiment in the dry season were 0.3 ^{o}C higher than that in the rainy season.

Growing degree days (GDD) required by mungbean for flower development in the rainy season was generally higher than that in the dry season. However, GDD required for pod maturity in the rainy season was lower than in dry season. The exception was for Fore Belu that required the same GDD forflower development and required higher GDD for pod maturity in the rainy season than in dry season. According to Tzudir et al. (2014), the rising of air temperature increased the GDD requirement by the plants. At the first month of the rainy season, the air temperature was higher than that for the first month of the dry season, and there was no rainfall (Table 1). Therefore, the amount of GDD for flowering in the rainy season was higher than that in the dry season. At the second month, when the plant entered the pod formation until pod maturity stages, GDD required in the rainy season was generally lower than that in the dry season. This presumably caused by the lower temperature in the rainy season due to precipitation. In addition, the higher GDD in dry season during pod set was caused by a higher difference between the minimum and maximum temperature (Table 1). Vima 1 had the lowest GDD while Fore Belu had the highest GDD for flowering and pod maturity in both rainy season and dry season.

Yield and yield attributes

Variety by growing season interaction affected grain yield, the weight of mature pods, plant population, and 1000 seed weight (Table 5). All varieties produced higher grains and pod yields in the rainy season than those in dry season except Fore Belu that produced higher seed and pod yields in the dry season. Kutilang produced the highest grains and pods yields, while Fore Belu produced the lowest. The grains and pods yields of all varieties more fluctuated in the rainy season than those in the dry season. Table 5 showed that the seed yield of Vima 1 and Kutilang in rainy season *i.e.* 2.04 t and 2.48 t ha^{-1} successfully exceeded its yield potentials of 1.76 t and 1.96 ha^{-1}, respectively. The seed yield of Fore Belu in both seasons, indeed, was higher than its yield potential (1.076 t ha^{-1}).

Climate, especially the amount of rainfall, affects mungbean yield, and the productivity increases along with the increase of rainfall (Ariyanto 2010). Four times of irrigations during the growing period of mungbean planted in dry season could not supply water as much as a number of rainfalls in rainy season (Table 1). In other words, mungbean crops received more water in the rainy season for their growth as compared to that in the dry season. Fore Belu variety, however, produced lower yield in the rainy season. This lower yield was supported by Trustinah et al. (2014) who reported that Fore Belu produced low yield when planted in soil with excessive/abundant water and, on the contrary, it produced higher yield when grown in less water condition. Abundant water from rains caused Fore Belu had a longer vegetative growth than the generative one.

To some extent, the weight of mature pods of mungbean determines its grains yield. The higher pod weight of Sriti, Murai, and Kutilang was followed by the higher seed yields of these varieties in rainy season. In the dry season, all varieties produced the same mature pod weights as well as grain yields.

Seed size is generally illustrated by the weight of 1000 seeds. Kutilang had the biggest seed size while Vima 1 had the smallest in both seasons. The seed sizes of Vima 1, Sriti and Kutilang were not substantially different either in rainy or dry season planting. Meanwhile, Murai and Fore Belu had significantly bigger seed size in the dry season (Table 5). This indicates that the seed size of Murai and Fore Belu was influenced by environment i.e. growing season. According to Hampton et al. (2016), the variation of climate as expressed in the different growing season could affect the seed mass because of the changes of seed growth rate and seed filling duration.

There was a higher number of plants at harvesting time in the rainy season than that in the dry season. Vima 1 had the highest plant population in the rainy season, while Murai, Kutilang, and Sriti had the highest numbers in a dry season among the tested varieties.

Number of pods plant^{-1} was only influenced by growing season, where rainy season resulted in 56.6% higher pod numbers than the dry season. All five varieties had the same amount of pods plant^{-1} (Table 6). In more detail, the differences in pod numbers plant^{-1} between the growing seasons were likely caused by the differences in pod growth rates as discussed in Table 3. The higher pod growth rate accelerated the pod formation of mungbean plant.

Table 4. Flowering date, growing degree days (GDD) of flowering, maturing date and growing degree days (GDD) of maturing of mungbean varieties on different growing seasons

Growing season	Varieties				
	Vima 1	**Sriti**	**Murai**	**Kutilang**	**Fore Belu**
	Flowering date (DAS)				
Rainy	36.00 d	37.00 bc	37.50 a	36.50 cd	38.00 a
Dry	34.00 f	35.00 e	37.50 a	36.50 cd	38.00 a
	GDD of flowering (^{o}Cd)				
Rainy	645.953d	660.778 bc	669.478 ab	653.795 cd	677.319 a
Dry	608.420 f	626.517 e	645.594	626.517 e	677.997 a
	Maturing date (DAS)				
Rainy	55.00 d	59.00 b	59.00 b	55.00 d	65.00 a
Dry	55.50 d	56.50 c	56.75 c	56.50 c	58.50 b
	GDD of maturing (^{o}Cd)				
Rainy	900.750 e	964.093d	964.093	900.750 e	1067.576 a
Dry	968.873d	985.198 c	989.233 c	985.198 c	1016.364 b

Note: Values inone variable followed by the same letter (s) were not significantly different at LSD 5%. DAS=days after sowing, GDD=growing degree days

Table 5. Grain yield, weight of mature pods, plant population, and 1000 seed weight of mungbean varieties on different growing seasons

Growing season	Varieties				
	Vima 1	**Sriti**	**Murai**	**Kutilang**	**Fore Belu**
	Grain yield (t ha^{-1})				
Rainy	2.04 c	2.15 bc	2.35 ab	2.48 a	1.10 e
Dry	1.02 e	1.22 de	1.34 d	1.13 de	1.23 de
	Weight of mature pods (t ha^{-1})				
Rainy	2.62 b	3.58 a	3.51 a	3.56 a	1.34 e
Dry	1.91 d	2.33 bcd	2.35 bc	2.00 cd	2.08 cd
	Plant population ha^{-1}				
Rainy	491.250 a	453.500 ab	452.256 ab	413.000 bc	455.250 ab
Dry	303.250 d	363.000 c	359.750 c	363.000 c	297.500 d
	1000 seed weight (g)				
Rainy	55.65 ef	63.53 bcd	52.60 f	71.88 a	55.20 ef
Dry	58.25 def	60.63 bcde	58.78 cde	66.10 ab	64.65 bc

Note: Values inone variable followed by the same letter (s) were not significantly different at LSD 5%

Table 6. Number of pods per plant of mungbean varieties in different growing seasons

Treatments	Number of pods plant^{-1}
Growing season	
Rainy season	23.10 a
Dry season	14.75 b
Varieties	
Vima 1	16.25
Sriti	19.75
Murai	19.38
Kutilang	17.75
Fore belu	21.50

Note: Values in the same column and treatment that followed by the same letter (s) were not significantly different at LSD 5%

Correlation coefficient

The relationship between growth rate, pod partitioning, phenology traits, yield components and seed yield was determined by the correlation coefficient. Growing season caused a different effect on the observed parameters (Table 7). Rainy season emphasized the significant role of phenological traits on seed yield, yield component (number of pods plant^{-1}), and growth rate (pod growth rate and plant height). Dry season, however, born the significant role of phenological traits on different parameters i.e. pod partitioning, growth rate (stem growth rate, leaves growth rate, and plant height).

In the rainy season, seed yield was positively correlated to the growth rate (pod growth rate, total dry biomass growth rate), and yield component (mature pod weight), but negatively correlated to phenology traits (flowering date, maturing date, plant height) and a number of pods plant^{-1}. Pod growth rate declined when the pod numbers increased. The high pod growth rate was characterized by the low plant height, the short flowering and maturing dates. In the dry season, seed yield was positively correlated to the growth rate (pod growth rate, total dry biomass growth rate), and yield component (mature pod weight, plant population) while phenology traits had significant correlation with seed yield.

In both seasons, the main components that were positively correlated to seed yield included pod growth rate, total dry biomass growth rate, and mature pod weight. These results were in line with the results of Mondal et al. (2011) and Mondal et al. (2012) who found that seed yield was positively correlated to total dry biomass. Mature pods weight was positively and significantly related to pod growth rate, and total dry biomass growth rate. The increase of pod growth rate would increase the pod weight and pod partitioning, therefore, increased the seed yield. In these two growing seasons, the seed yield did not correlate to seed size, and seed size was not correlated to any single parameter observed (Table 7). However, seed size of Vima 1, Sriti, Kutilang was similar either in rainy or dry season except for Murai and Fore Belu (Table 5). Table 5 shows that the larger seed was not always resulted in higher seed yield. The absence of correlation between seed size and seed yield in this study was in line with a report by Gul et al. (2008) who stated that seed size of mungbean was not significantly correlated to seed yield. This means that genetic factor is more dominant in controlling seed size rather than the environmental factors. Even though the 1000-seed weight was more genetically controlled trait, it could be affected by the growing season. It is apparent in the field that seed size could be smaller or larger than that mentioned in the description list. To certain varieties, the seed size changed when the plants were grown in different seasons. For examples: the seed size of Murai and Fore Belu was, respectively, 10% and 15% lower when planted in the rainy season. Based on correlation coefficients, a factor that mostly contributed to seed yield was the weight of mature pods. Meanwhile, Ahmad et al. (2015) reported that pod number plant^{-1} was positively correlated to seed yield, but the parameters of plant height and number of branch per plant have a maximum direct effect on seed yield.

In summary, the growing season affected plant growth rate, pod partitioning, phenology and seed yield and yield components with rainy season influenced more parameters of plant growth rate, crop phenology, seed yield and its components. Conversely, dry season had more effect on pod partitioning coefficient, total dry biomass rate, and seed size. Yield variation among five varieties showed that average yield in the rainy season was 75 to 119% higher than those in dry season except Fore Belu that had the same yield in both seasons. There was significant interaction effect of variety and growing season on the total dry matter and pod growth rates, days to flowering, days to maturing pod, plant height, seed yield, plant population, the weight of mature pods, and 1000-seed weight. The variation of growth rate, phenology, and yield of mungbean between growing seasons were affected by the differences between minimum and maximum temperatures and the amount of rainfall. Despite its short duration type, high pod growth rate, and simultaneous harvest, Vima 1 had reasonably high seed yield.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the ACIAR (Australia Centre for International Agricultural Research) Project No. SMAR/2007/068 on "Productivity and Profitability Enhancement of Tropical Pulse in Indonesia and Australia" which funded the experiment, and also Ir. Abdullah Taufiq, MP and the technicians for their great assistance in conducting the trials.

Table 7. Coefficient of correlation of parameters in two growing seasons

Para meters	**Rainy season**												
	FD	**MT**	**PH**	**LGR**	**SGR**	**PGR**	**TDM**	**PT**	**PW**	**SS**	**NP**	**PP**	**Y**
FD	■	0.73**	0.56**	0.06	0.50*	-0.47*	-0.29	-0.32	-0.40	-0.19	0.58**	-0.22	-0.53*
MT	0.88**	■	0.88**	-0.10	0.10	-0.80**	-0.67*	-3.30	-0.64**	-0.40	0.67**	0.02	-0.79**
PH	0.87**	0.87**	■	-0.19	-0.04	-0.80**	-0.77**	-0.18	-0.69**	-0.14	0.66*	-0.11	-0.81**
LGR	0.65**	0.65**	0.57**	■	0.50*	0.27	0.67**	-0.43	0.02	-0.03	0.01	-0.32	0.07
SGR	0.51*	0.49*	0.40	0.94**	■	0.03	0.38	-0.42	0.20	0.09	0.31	-0.29	0.14
PGR	-0.22	-0.33	-0.31	-0.05	0.08	■	0.85**	0.50*	0.60**	0.11	-0.6**	0.19	0.67**
TDM	0.46*	0.40	0.34	0.88**	0.92**	0.41	■	0.02	0.58**	0.13	-0.45*	-0.05	0.65**
PT	-0.58**	-0.64**	-0.54*	-0.79**	-0.70**	0.62**	-0.45*	■	0.29	0.04	-0.34	0.31	0.21
PW	0.16	0.15	0.11	0.31	0.29	0.63**	0.56*	0.13	■	0.41	-0.43	-0.13	0.90**
SS	0.30	0.36	0.16	0.16	0.21	-0.05	0.12	-0.19	-0.09	■	0.31	-0.41	0.43
NP	0.00	0.07	-0.10	-0.14	-0.22	-0.20	-0.22	-0.04	0.02	-0.23	■	0.17	-0.49*
PP	-0.20	-0.03	0.00	0.03	0.08	0.34	0.18	0.17	0.57**	0.04	-0.06	■	-0.12
Y	0.35	0.32	0.33	0.30	0.22	0.50*	0.48*	0.09	0.88**	-0.07	-0.04	0.45*	■

Dry season

Values above shading cells are correlation coefficients in rainy season, and those below are correlation coefficients in dry season. FD= flowering days, MT=maturing days, PH=plant height, LGR=leaves growth rate, SGR=stem growth rate, TDM=total dry mass growth rate, PGR=pod growth rate, PT=pod partitioning, PW=weight of maturing pods, SS=1000 seed weight, NP=number of pod per plant, PP=plant population, Y=yield, *=significant at 0.05 probability level, **= significant at 0.01 probability level.

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