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Improving of Kidney Bean Production by Plant Spacing in Two Different Altitudes at South Central Timor Regency, Indonesia

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Abstract: The production of kidney bean as the source of protein and carbohydrate for the people of South Central Timor Regency is still low, therefore the production should be increased. The aim of this study is to evaluate the growth and production of kidney bean based on the different altitudes and spacings. The research was conducted at two different altitudes in Southern Central Timor Regency, Indonesia. Nine spaces of planting system have been tried at each altitude. The research used nested design by 3 replications. The experimental plot was made of 3×4 m in size and there were 27 experimental plots on each altitude. Result of the research showed that kidney beans were produced and grown well on the medium altitude compared with the high altitude. The rainfall, light intensity and temperature were the most dominant climatic factors that affected the growth and production of kidney bean among altitudes. Spacing of 30×10 cm was the most suitable for both altitudes based on yield of the crops. Spacing of 50×30 cm, 50×20 cm and 30×30 cm have provided better yield stability than other spacing as a result of different altitudes.

Keywords: Kidney Bean, Different Altitude, Climate, South Central Timor Regency

Introduction

Kidney bean in South Central Timor Regency (SCTR) is commonly planted above 900 m asl (above sea level) altitude. South Central Timor Regency community uses this commodity as complement of their main consumption. Crop short life span is very suitable to be planted in SCTR which classified as type D area based on the Oldeman classification. Its ability to stay persistent allowed it to be kept as food reserve during dry season. Kidney beans have been planted on several high lands in SCTR but the total of its production has been decreased for the last 5 years. The Development of kidney beans planting on lower land should be done, but it will be limited by climatic differences. Different altitudes may cause climatic factors differences, such as light intensity, temperature, rainfall and humidity. Temperature in higher altitudes is low. Sugito (1999) suggested that the temperature will decrease 3°F each of 1000 feet altitudes. In general, the evapotranspiration rate would be greater on low land than on high land. The Growth rate will be optimal if the crops are in convenient condition and the other factors will not become limitation.

Different altitudes level will affect the soil precipitation and humidity that could create drought stress. A Less profitable of planting location, particularly for crops growth and harvest, should be overcome by improving the micro-climatic condition. Serious damage that caused by high temperature will affect new tissues to experience proplasm denaturation through dehydration. During the formation of generative cells, high temperature will disrupt mytosis on cytokinesis phase. This condition failed the seed formation because of the steril products of pollen grains.

Plant spacing arrangement is intended to suppress intra-crops and inter-crops competitions, also create more conducive micro-climatic condition for crops growth and development. Spacing arrangement will determine the crop populations, which also affect the harvest yield. However, the increasing number of population also reduced the yield due to strict competition among crops.

In general, the decreasing of space between crops would increase yield per plot. However, the highest yield per plot was obtained from less density of crops even though maximum yield per plot was obtained from the highest density. Gardner *et al*. (1985) stated that competition among crops on wider plant spacing became less, but it greater within the crop's organs. Furthermore, competition between crops in a group with medium density occurs during flower initiation or flower formation. Higher density of crops will reduce the amount of harvested seeds due to the competition which occurred during the formation of flower bud. Khan *et al*. (2010) examined the lowest chickpea seed yield per hectare in different plant spacing was on the narrowest plant spacing. The aim of this research is providing the basic information for increasing kidney beans production in South Central Timor Regency, Indonesia.

Materials and Methods

The research was conducted in two different altitudes in South Central Timor Regency, Indonesia. High altitude was located in Netpala village (Netpala (9°44'35,56"S, 124°16'06,65"E;1112 asl). Medium altitude was Bentulu Village (9°53'59,70"S, 124°13'09,71"E; 473 asl). Plot design was used Randomized Block Design analysis. The first factor was Altitude (A) that included A1 (high altitude) and A2 (medium altitude). The second factor was plant spacing (J), which included: J1= 30×10 cm (400 crops/plot), J2= 30×20 cm (200 crops/plot), J3= 30×30 cm (133 crops/plot), J4= 40×10 cm (300 crops/plot), J5= 40×20 cm (150 crops/plot), J6= 40×30 cm (100 crops/plot), J7= 50×10 cm (240 crops/plot), J8= 50×20 cm (120 crops/plot), J9= 50×30 cm (80 crops/plot).

The repetition was focused on the altitudes level. There were 27 experimental plots on each altitude. The size of each experimental plot was 3×4 m = 12 m^2 and 25 cm of plot height. Seeds which used in this experiment were kidney bean of *Ine Rie Ngada* variant. Fertilizer which used were 30 ton/ha (36 kg/plot) of manure and NPK fertilizer (15, 15 and 15%) or about 460 kg ha^{-1} (552 g/plot) as basic and supplemental fertilizer. The seeds of kidney bean were planted in definite plant spacing accordance with treatment. Two seeds were laid in each planting hole. Thinning was done by leaving behind a crop for each planting hole. Irrigation was only relied on the rainfall. The average temperature, humidity, rainfall, wind velocity and global light radiation during research were reported as average data of each day.

Data Collection

Total of crops dry weight was obtained by oven-dried. Crops samples were oven-dried at 70°C for 2×24 h. Dry weight of crops was measured using analytic scales. Crop Growth Rate (CGR) was measured based on the increasing of crops total dry weight on soil surface per time unit which measured every 2 weeks:

$$Equation: CGR = \frac{W2-W1}{T2-T1} x \frac{1}{GA}\left(g\ cm^{-2} day^{-1}\right)$$

Notes:

W1 and W2	=	Crops total dry weight on two destructive observations, T1 and T2
T1 and T2	=	Days of the crop (in days)
T1	=	First observation
T2	=	Second observation
GA	=	Width of the land (spacing)

The observation on flowering days was done by counting the required time for each crop to flower or at least 50% crops in each plot have been flowering. Numbers of pods per crop were obtained after harvest time by calculating the numbers of pods on square which divided with the numbers of all crops on square. The size of square was 2×1 m. The average of crop seed weight per hectare was calculated from seed weight on square which divided with the number of all seed on squares. The weight of 100 seeds was obtained from means of 3 times weight measurements of seeds in each plot. The seed weight per hectare was measured by converting the number of seed weight in each square into hectare unit. Other supporting data, such as rainfall, temperature, humidity, maximum wind velocity and global radiation were obtained from the climatology station of the South Central Timor Regency which managed by the Center of Agricultural Technology of East Lesser Sundas (East Nusa Tenggara) Province. The crop micro climate data in each experimental plots were light radiation interception efficiency, soil temperature and soil humidity. The light radiation interception efficiency was measured by using Luxmeter type LX 1010BS. The soil temperature was measured by using soil thermometer and Soil humidity was measured by using soil moisture tester.

Data Analysis

The observation data for each Altitude was analyzed by using ANOVA following the Randomized Block Design mode and continued with orthogonal contrast test. The Combined Analysis of Variance was examined by following the nested design with nested repetition on each altitude. The combined orthogonal contrast test was applied to study the effect of both inter-row and intra-row plant spacings on the observed variables. The Interaction between plant spacing and altitude factors was described by calculating the differences between total middle quadratic contrast of both altitudes and the combined middle quadratic contrast (Gomez and Gomez, 1984). The contrast test of each altitude was following the comparison below:

- Inter-rows:
  (J1, J2, J3) Vs (J4, J5, J6, J7, J8, J9)
- (J4, J5, J6 Vs J7, J8, J9)
- Intra-Rows on Inter-Rows of 30 cm
  J1 Vs (J2, J3)
  J2 Vs J3
- Intra-Rows on Inter-Rows of 40 cm
  J4 Vs (J5, J6)
  J5 Vs J6
- Intra-Rows on Inter-Rows of 50 cm
  J7 Vs (J8, J9)
  J8 Vs J9

Crop Growth Rate data (CGR) was not analyzed by using contrast test, but then presented in graphic using data of 2 weekly observations.

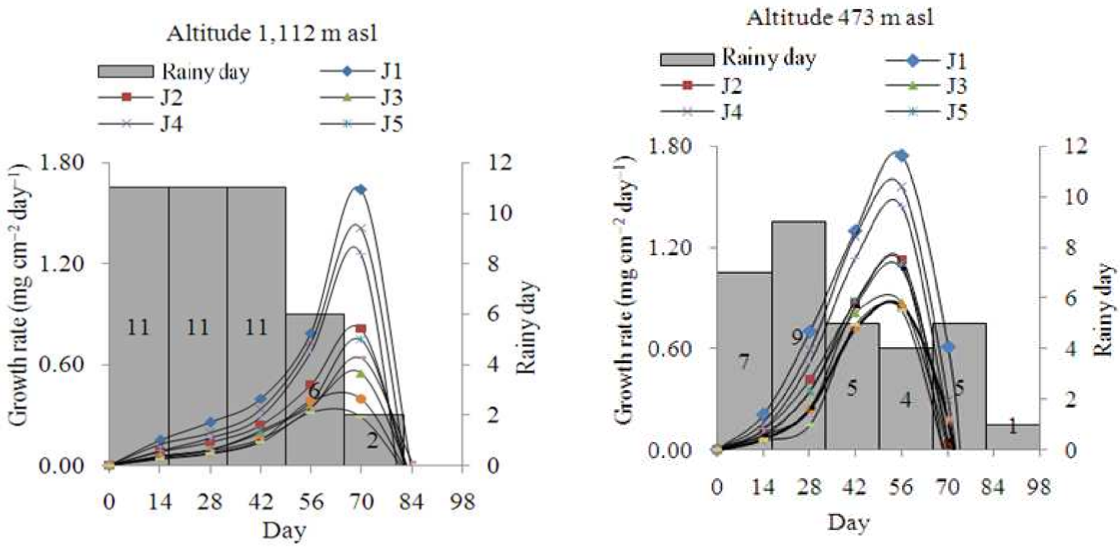
Results

Crop Growth Rate (CGR) of Kidney Bean

The Crop ability to accumulate dry matter per area unit each day could be seen from the growth rate. The Duration of rainfall affected the light radiation level as the result of cloudiness level, thus will also affected the CGR. CGR of kidney bean in different plant spacings and its connection with rainfall for each altitude are presented in Fig. 1. The Higher CGR was obtained in the narrower intra-row plant spacing (30×10 cm, 40×10 cm and 50×10 cm). This condition shows that the crop ability to accumulate dry matter per area unit is mainly determined by crop population. Data present the accumulation of dry matters which higher on crops grown on medium land, in comparison with crops grown on highland. The rainfall duration was the climatic factor which mainly affected on CGR.

Improving Kidney Bean Production

The changes on Seed weight as the result of interaction between plant spacing and altitude indicate that plant spacing is potential to bring different weights of seed per crop. The highest weights of seed on high land were obtained from plant spacing 50×30 cm and on medium land were obtained from plant spacing 40×30 cm. Plant spacing 30×10 cm was considered to produce highest and more stable weight of seeds in comparison with other plant spacings. Different climatic conditions between each location and the competition among crops have contributed to be different potential of plant spacing on controlling the weights of seed per crop. Generally, the crops adaptation to environmental condition will be reflected on both of vegetative and generative appearances which affected yield components. The Weight of seed per crop is closely related to dry weight of crop. Analysis of correlation between dry weight of crop and weight of seed per crop on high land show a very significant correlation (R^2 = 0.9596). Meanwhile, analysis of correlation between dry weight of crop and weight of seed per crop on medium land also show a very significant correlation (R^2 = 0.9596). Those correlations are presented in Fig. 2.



(a) (b)

Fig. 1. The rainfall effect on crop growth rate (mg $cm^{-2}day^{-1}$) in (a) Highland and (b) Medium land

Data show that kidney beans, which grown on highland are 11.1% higher in allocating the dry matters for the weight of seeds than on the medium land. The increasing potential of seed weight per crop on high land is 72.6% for each 1 gram of crop dry weight. Meanwhile, kidney beans on the medium land have an increasing potential of seed weight per crop about 61.5% for each 1 gram of crop dry weight.

The Lack of crops response to micro-climatic changes affects the crop seed weight which obtained per hectare. The increasing of population number on more dense plant spacing brought the highest weight of seed per hectare. Weight of 100 seeds represented the seed weight which obtained in each altitude. Analysis of correlation results between plant density and obtained seed weight per hectare show a significant correlation in kidney beans which grown on highland ($R^2 = 0.9058$) and on the medium land ($R^2 = 0.9561$). Analysis of correlation results between growth rate and seed weight per hectare also show a significant correlation on kidney beans which grown on high land ($R^2 = 0.9022$) and on the medium land ($R^2 = 0.9559$). Close correlation between plant density, CGR and seed weight of crop per hectare are presented in Fig. 3.

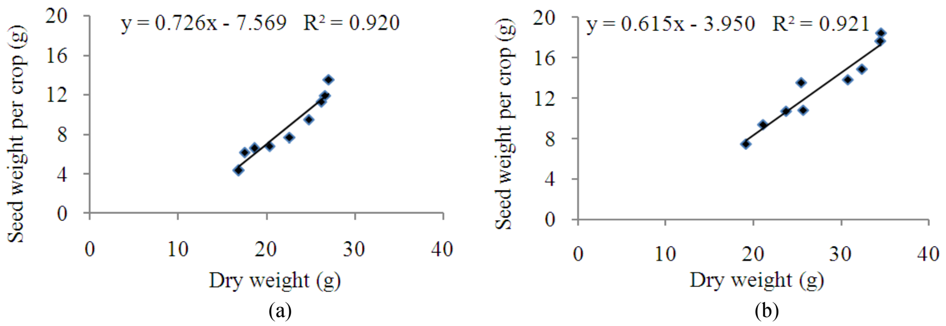


Fig. 2. Correlation between dry weight and weight of seed per crop of kidney bean on different spacing at (a) high plain and (b) medium plain

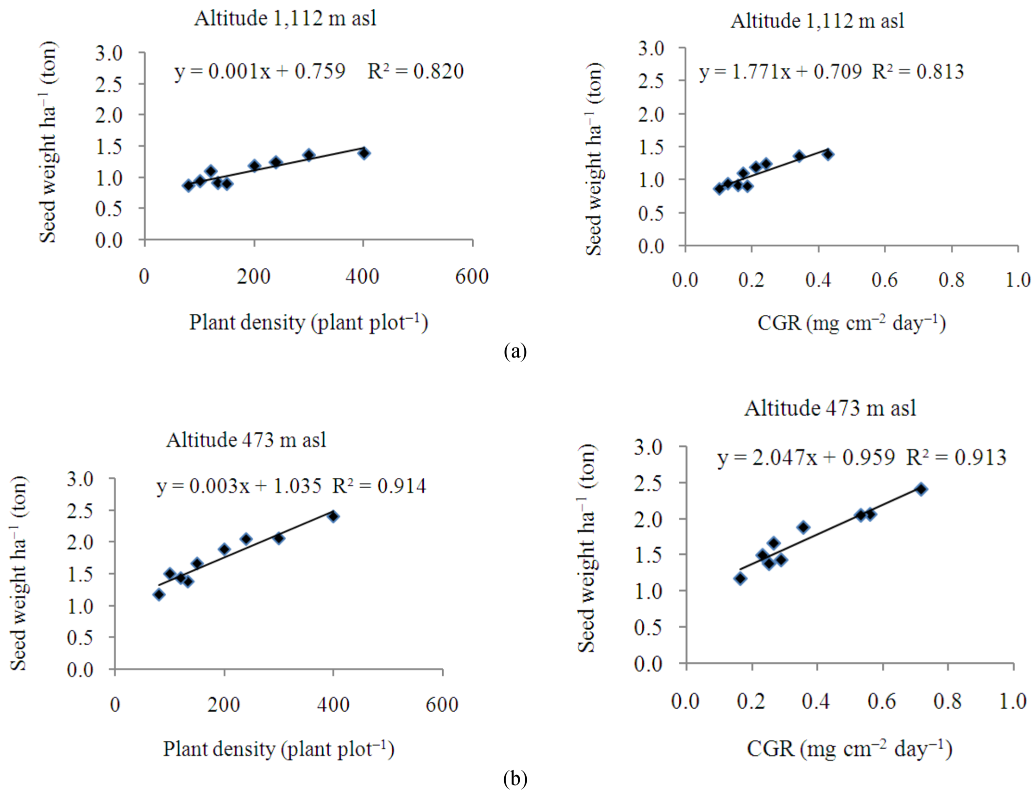


Fig. 3. Correlation of plant density, CGR and seed weight per hectare of kidney bean on different spacing at (a) high plain and (b) medium plain

It is important to note that the highest seed weights per hectare in this research were obtained by applying the most dense plant spacing (30×10 cm) which planted both on high land and medium land. Plant spacing 30×10 cm resulted 1.39 ton seed weight per hectare on high land and 2.40 ton seed weight per hectare on the medium land. The Obtained seed weights per hectare on both altitudes were higher than varieties yield potential, 1.2 ton ha^{-1}.

Discussion

The growth rate of kidney bean at different plant spacing showed different responses. The Longer rainfall along with high level of cloudiness and low light radiation intensity on highland during the initial growth were less beneficial for crops. The Changes of dry matter accumulation seemed very low. The production of dry matter increased drastically at the 56th day. During that duration, the crops have passed flowering phase and pod formation before entering the pod filling phase. The peak of CGR occurred at the 10th week or at the 70th day and then followed by the decreasing of CGR. However, dry weight as the result of leaf abscission reduced drastically which accelerated by low rainfall intensity and high temperature. The determination of planting time would be the right solution to improve kidney bean CGR which planted on highland.

CGR of the kidney bean which planted on the medium land has started to increase since 4 Weeks After Planting (WAP) or at 28 days after planting. This condition was related to its environmental support. Kidney bean on lower altitude with similar climatic condition as in Benlutu responded a better growth and production. Higher light radiation on the medium land was affecting the higher temperature and accelerating the flowering process and fruit production in comparison with highland. Moreover, other effect due to climatic condition on medium land was the shortness of dry matter accumulation as the result of shorter life cycle.

The Changes of CGR level due to plant spacing 30×10 cm was much greater than other plant spacings. This was the implication of interaction between plant spacings and altitudes. Meanwhile, plant spacing 30×10 cm have a greater change of growth rate in medium land than in highland. The applications of plant spacing 30×10 cm become more advantageous alternative for wider cultivation because it will increase yield characters.

The flowering period of kidney bean was not easily affected by plant spacing arrangement, but it was different along with the altitudes as well. The climatic differences between both altitudes have caused a difference on growth period. Kidney beans which planted on medium land relatively have faster flowering period than kidney bean which planted on highland. Kidney bean on the highland takes 35.85 days for flowering on average. On the other hand, it takes 31.93 days on average when it planted on medium land. Different flowering period could be related to the different temperature and light radiation levels between both altitudes. Low temperature and light radiation inhibit the induction of kidney bean flowering that grow on highland.

The Plant spacings 50×30 cm, 50×20 cm and 30×30 cm are the best plant spacings on increasing yield stability for each altitude which shown from crop yield performance. However, the obtained data of seed weight was not the highest results. It shows that plant spacing is very important to be concerned in kidney bean breeding on different altitudes. Mureithi *et al*. (2012) reported that 30×20 cm of plant spacing resulted the highest rate of French bean (*Phaseolus vulgaris*) growth, but the analysis of benefit cost ratio showed that the ideal plant spacing was 30×15 cm. Meanwhile, based on the beans breeding guidance by the DAFFRSA (2010) recommended that plant spacing of 90×15 cm for white kidney. Abubaker (2008) reported yield of bush bean harvest (*Phaseolus vulgaris*) was higher in 90×20 cm of plant spacing. Amato *et al*., (1992) reported that faba bean (*Vicia faba*) flowers had abscission due to competition among crops as a response to the environment. Meanwhile, Khorshidi *et al*. (2009) reported that different densities of fennel cultivation have shown a significant influence on seed yield.

Conclusion

Kidney beans grow and produce more yields on medium land than on high land. The Rainfall, light radiation intensity and temperature are the climatic factors which mainly affect kidney bean growth and production between each altitude on the location. Plant spacing 30×10 cm is the suggested spacing for both altitudes based on crop yield number, it yielded 1.39 ton per hectare on high land and 2.40 ton per hectare on medium land. Plant spacing 50×30 cm, 50×20 cm and 30×30 cm contributed better yield stability than other plant spacings as the result of different altitudes. This information could provide basic data for government and community as a standar for planting kidney beans and increasing the production as the main commodity in South Central Timor Regency, Indonesia.

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Author's Contributions

I Komang Sudarma: Participated in all experiments, data collector, coordinated the data-analysis and contributed to the writing of the manuscript, analysis and interpretation of data.

Nurul Aini: Designed the research plan and organized the study, give final approval of the version to be submitted and any revised version.

Karuniawan Puji Wicaksosno: Experiment design, give final approval of the version to be submitted and any revised version.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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