Research

Effects of Different Soil Treatment Methods on the Performance of Green Bean Plants (*Phaseolus vulgaris L.*)

Efeitos de diferentes Métodos de Preparo do Solo no Desempenho da Cultura do feijão-verde (*Phaseolus vulgaris L.*).

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Abstract: The performance of green bean plants (*Phaseolus vulgaris L.*) under different soil treatment methods was assessed in a field experiment conducted on the campus of Escola Superior de Desenvolvimento Rural (ESUDER) in Vilanculos. The experiment consisted of a randomized block design with three treatments (CM-Conventional Method of soil preparation, CMM-Conventional Method of soil preparation with a mulch cover, and DPM-Direct Planting Method) in four (4) replications. Seed germination, plant height and bean pod production were determined for each soil treatment. Seedling emergence was observed at eight (8), ten (10) and twelve (12) days after sowing (DAS) under MCM, MC and DPM, respectively, and the maximum plant height was recorded 49 DAS in all treatments. Plant height was higher under CMM until at about 35 DAS, but was similar under the CM and CMM thereafter. However, the average growth rate was higher under the CM. The number of bean pods produced per plant was higher under the CM, while the length of pods was similar under the CM and CMM. The different methods of soil preparation had no significant effect (P>0.05) on green bean pod weight, and the total yield of bean pods. Therefore, the CMM provided a better environment for seed germination, but the added mulch cover had no effect on plant growth rate and on production of green bean pods. The authors wish to thank Celio Alho, Edna Chicico, Edson de Brito and Nilza Guambe for their assistance in soil preparation and data collection.

Resumo: O desempenho do feijão-verde (*Phaseolus vulgaris L.*) sob métodos diferentes de preparo do solo foi avaliado em um experimento no campo da Escola Superior de Desenvolvimento Rural (ESUDER) em Vilanculos, utilizando-se o delineamento de blocos completos causalizados, com três tratamentos do solo (Método de preparo do solo Convencional -MC, Método de preparo do solo Convencional com Mulching - MCM, e
Método de Plantio Direto - MPD), e quatro (4) repetições. Para cada tratamento, foram realizadas avaliações da germinação de sementes, altura das plantas, e a produção de vagens verdes. Foi observado a emergência das mudas das plantas oito (8), deis (10) e doze (12) dias após semear (DDS) em tratamentos MCM, MC e DPM, respetivamente, e a altura máxima das plantas ocorreu 49 após o semear, em todos os tratamentos. A altura das plantas foi maior sob C MM até 35 DAS mas era semelhante sob CM e CMM depois disso. Porem a taxa de crescimento foi maior sob CM que resulto também em maior número de vagens verdes per planta. O comprimento de vagens de vagem era maior sob os métodos convencionais (MC e MCM), mais as variáveis peso e produtividade de vagens verdes não foram significativamente influenciado (P> 0,05) pelos diferentes métodos de preparo de solo usados no presente estudo. Conclui-se que a adição do mulching no método convencional de preparo do solo proveu um ambiente melhor para germinação de sementes, mas não tive efeito na taxa de crescimento do feijoeiro e na produtividade de vagens verdes. Os autores desejam agradecer Cêlio Alho, Edna Chicico, o Edson de Brito e Nilza Guamba para a ajuda deles na preparação do solo e coleção de dados.

Keywords: Green Beans, Soil Preparation Methods, Mulching
Palavras chaves: Feijão-Verde, Métodos de Preparo do Solo, Mulching

1. Introduction

Green Bean (Phaseolus vulgaris L.) is one of the most valuable legumes crops in the world because of its important contribution to human diet. It is cultivated in the tropical and subtropical areas particularly in North and South America; contributing roughly 47% of the world production, whereas production in eastern and southern Africa account for 10% of the global production. In Mozambique, the largest areas of green bean production are in the northern part of country, in the provinces of Tete and Niassa, with the latter being more productive because of its favorable climatic conditions. It is also cultivated in the central part of Mozambique, especially in the province of Manica during the rainy season, whereas in the southern part of the country, it is cultivated in the Provinces of Maputo and Gaza during dry seasons under irrigation. This legume crop has great social and economic importance in Mozambique because it provides the necessary food supply to satisfy the needs of the country’s low-income population characterized by a relatively high growth rate. It is also an important source of revenue for smallholders who devote their time for its production (FILGUEIRA, 2000 and HEEMESKERK (1993). For the purpose of this study, soil preparation methods consist of a series of farming operations done prior to sowing the seeds on the ground. They include turning over the top soil and exposing the lower layers, incorporating crop/plant residues into the soil, applying fertilizers, or covering the soil surface with dead plant residues or mulch, etc. (FOLLE & SEIXAS, 1986). While other studies assessed the effects of different soil preparation methods on bean plants elsewhere (SANTOS et al., 2010), information on the impact of different methods of soil preparation on
agronomic characteristics of green bean plants grown on predominantly sandy soils in the
district of Vilanculos is lacking. Furthermore, the increasing interest in green bean production
amongst local farmers calls for a clear understanding of the effects of different methods of
soil preparation on this valuable crop under the edaphic-climatic conditions of Vilanculos.
Such information will be of great interest to local producers and to agriculturalists, in general.

2. Materials and Methods

2.1 Geographical location of the site

The experiment took place on the campus the Escola Superior de Desenvolvimento Rural (ESUDER), one the Universidade Eduardo Mondlane (UEM) schools located in the coastal town of Vilanculos, at coordinates 21°59′30.6″ S and 035°16′14.8″ E, southern hemisphere with an average altitude of 49 m above sea level. The town of Vilanculos is located in the district of the same name, within the province of Inhambane in Mozambique.

2.2 Climatic condition

According to the Köppen-Geiser classification, the climate of experimental area is Aw, corresponding to a dry tropical climate, with an annual precipitation averaging 733.9 mm, and an annual average temperature of 24.5°C (Max. average 28.6°C, and Min. average 19.9°C.) The hottest periods are November to March, but the remaining months are dry with cool temperatures (MICOA, 2009; MOTHER, 2005).

2.3. Soils

The soils in the study area are sandy and permeable in the coastal areas, whereas sandy-loam and loamy-clay soils are prevalent in the interior (MOTHER, 2005). Table-1 shows the soil physical and chemical compositions for the experimental site situated at approximatively 10 km from the coastal line.

Table 1: Results of soil analyses from the ESUDER Laboratory.

<table>
<thead>
<tr>
<th>Soil Depth (0 – 15 cm)</th>
<th>Soil Chemical Components (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>(0 – 15 cm)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Source: Chiçico (2016).

2.4 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three treatments and four replications. The experimental units were set-up on 12 parcels of 2.88 m² each.

2.4.1 Treatments details

Three (3) treatments were randomly assigned to the experimental blocks.
T1 **CM** - Conventional Method of soil preparation;  
Natural vegetation removed, soil turned over with a manual hoe to an average depth of 0.30m, and soil surface raked and leveled

T2 **CMM** - Conventional Method of soil preparation with a mulch cover  
Natural vegetation removed, soil turned over with a manual hoe to an average depth of 0.30m, soil surface raked and leveled, and mulch layer added to soil surface

T3 **DP** - Direct Planting Method  
Natural vegetation was removed with a hand hoe without revolving and without leveling the soil surface

### 2.5 Soil preparation and planting

The experimental units were set-up on 12 parcels of 2.88 m² each. On parcels designated for the “Conventional Method” of soil preparation and “Conventional Method with Mulching”, natural vegetation was removed, the soil was turned over with a manual hoe to an average depth of 0.30m and the surface was raked to level the soil thereafter. The parcels for the Conventional Method with mulching were covered with dead plant material following the soil preparation. The parcels for the “Direct Planting Method” underwent minimum preparation, whereby the natural vegetation was removed with a hand hoe without revolving and without leveling the soil.

Seeds of green bean cultivar «Garden Beans - Class ACT - Hygrotech® South Africa» were sown on all parcels by placing three (3) seeds in each hole at a depth of 2.0 cm. Twenty (20) days after seeding, excess bean seedlings were removed, leaving just one bean plant seedling per hole in each crop line for the study.

### 2.6 Soil fertilization

Soil fertilization consisted of applying bovine manure at the rate of 15 tons/ha one week before sowing, and thirty days after sowing. Just before the bean plants reached the flowering stage, manure was applied once more at the rate of 20 tons/ha.

### 2.7 Irrigation

Each parcel was irrigated with 20 liters of water at 2-day intervals, from sowing date to the beginning of the flowering stage, then watering was applied daily until harvest date.

### 2.8 Weed Control
Weed control was done manually following sowing, and throughout the growth period until harvest date, by hand plucking them from the parcels covered with mulch, and using a manual hoe on parcels with no mulch cover.

Data Collection

Seed germination
Seed germination and the number of days for germination during the first weeks following sowing was determined by counting the number of emerged seedlings during each observation period.

Plant height
Plant height was determined at 15, 21, 28, 35, 42 and 49 days after sowing, by measuring plant samples with a 30 cm ruler, from the soil surface to the maximum height of the fully expanded terminal leaf.

Plant Growth Rate
Growth rate was based on the rate of plant height increase over time. This was determined by: (1) the ratio of change in plant height between consecutive sampling dates over the number of days between sampling dates, and (2) the ratio of change in plant height between the initial and final sampling dates over the number of days between the first and last dates of plant height measurements. In either case, the determination of “Growth Rate” was according to Equation 1.

Flowering
Flower emergence was determined by observing green bean plants in each block under each treatment for signs of inflorescence emergence.

Green Bean Pods
The Number of Green Pods per plant, Length and Weight of green pods, and Yield of green pods per treatment were determined upon harvest.

Number of pods produced
The number of green pods per plant was determined by a simple count of pods produced from the sample plants.

Length of pods
Bean pod from the plant samples were measured from one extremity to the other with a 30 cm ruler, and the average weight of the green bean pods per plant was obtained based on the total weight of the green beans and the number of green bean pods for each plant.

Yield
The yield of green bean pods was determined by weighting all pods from each treatment in
each block with a precision scale (1g-500g), and the results expressed in tons per hectare (ton/ha.)

Data Analyses

Data from the experiment were analyzed using the SPSS Statistics software (v.20, IBM SPSS Chicago). The statistical analyses included analyses of variance (ANOVA), followed by multiple comparisons with Tukey HSD (α = 0.05). Furthermore, homogeneity of the variances was verified through Levene’s test (α = 0.05), and correlation analyses were performed to determine associations between yield of green bean pods, and the following variables: number of green bean pods, average weight of green bean pods, length of green bean pods, and plant height. Finally, graphical illustrations were produced with the use of Microsoft Excel program.

Result and Discussion

Germination and number of days for germination.

The conventional method of soil preparation with the addition of mulch (CMM) resulted in significantly higher percent (%) germination and lower number of days for germination (P<0.05), than the conventional (CM) and the direct planting methods (DPM) (Table 3.) The rapid emergence of green bean seedlings under CMM was attributable to mulching effect. Previous studies reported that the presence of mulch on the soil surface elevates soil humidity level and thus, provides suitable temperatures for germination, as compared with soils without cover (SANTANA et al, 2001). Considering the erratic precipitation patterns and the soil characteristics in the district of Vilanculos, these results should encourage the practice of mulching for a more efficient germination of green bean crops.

Table 3. Percent germination and number of days for germination under 3 soil preparation methods

<table>
<thead>
<tr>
<th>Soil Preparation Method</th>
<th>Percent (%) Germination</th>
<th>No. of Days for Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>84.28a</td>
<td>9.50a</td>
</tr>
<tr>
<td>Conventional + Mulch</td>
<td>99.01b</td>
<td>8.00b</td>
</tr>
<tr>
<td>Direct Planting</td>
<td>84.28a</td>
<td>11.75c</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column are not significantly different (α=0.05)

Plant Height
Results from the analysis of variance (ANOVA) based upon the general linear model showed that “Soil Preparation Methods” and “Date” each had significant effects (P<0.05) on green-bean plant height. The interaction (Treatment x Date) also had a significant effect on green bean plant height. The average plant height under each treatment followed a pattern of linear progression, steadily increasing from one sampling date to another (P<0.05) until the forty-ninth day, at which point plant height appeared to show a tendency to stabilize (Fig.1).

Figure 1. Average plant height (cm) per treatment per date

Green Bean plant height was significantly higher under the CMM compared with the other treatments at 15 and 21 days after sowing. Although the differences between CMM and CM were not statistically different thereafter, plant height was higher under CMM from 21 days through about 39 days, but plant height was slightly higher under CM compared with CMM at 42 and 49 days after sowing. The DPM resulted in relatively similar plant height to the CM at 15 days, but plant height remained lower under DPM than under CM and CMM throughout the remainder of the study period. Moreover, the differences in plant height between the DPM and CM was not statistically significant during much of the sampling period (28 days – 49 days after sowing), but height differences between CMM and DPM were significant (P<0.05) from the first sampling date until 42 days after sowing. The lower plant height observed under DPM was attributed to soil compaction, as the plots for this treatment received minimum soil preparation as opposed to the conventional methods.

Figure 2 illustrates the average growth pattern under all 3-soil preparation methods (CM, CMM, and DPM) throughout the sampling period. The average plant height also followed a linear progression through the sampling dates. Interestingly, no significant differences in
plant height were observed between consecutive sampling dates. However, height differences were significant between dates when the sampling interval is greater than 7 days. These results suggest that sampling intervals of 7 days was adequate for estimating green bean plant growth under the conditions where this study was conducted.

Figure 2. Average plant height (cm) across treatments per sampling date

When averaged across sampling dates, the conventional method with mulching (CMM) resulted in an overall greater plant height, averaging 21 cm, followed by the conventional method (CM) with 18.94 cm. The direct planting method (DPM) resulted in lowest height of green bean plants, averaging 16.31 cm (Fig 3.) The overall plant height under CMM was significantly higher (P<0.05) than under DPM. However, there was no significant differences in plant height between CMM and CM, and between CM and DPM. These results confirm that mulching provided a better and favorable environment for plant growth (CARVALHO, 2007). However, the results of the present study suggests that mulching influenced seed germination (Table 3) and seedling elongation during the initial stages (days 15 to 35) after sowing, but once the green bean plants were established (35 days and beyond), mulching did not appear to have any effect on plant height (Fig.1).
Plant Growth Rate

According to Suk et al. (2011), plant growth involves increase in size of tissues and organs as well as weight, or biomass accumulation. In this experiment, plant growth is expressed in terms of increase in plant height, which is the increase in length of Green Bean plant organs stems and leaves. Therefore, Plant Growth Rate in this study is the rate of increase in Green Bean plant height over time. More in-depth plant growth studies addressed Growth Rate as either Relative Growth Rate (RGR), Specific Growth Rate (SGR), or Absolute Growth Rate (AGR) using different mathematical formulas. The present study involved the calculations of Absolute Growth Rate of Green Bean Plants based on Equation-1 below.

**Equation-1: Calculation of Absolute Growth Rate**

\[
GR = \frac{dHt}{dT} = \frac{(Ht_2 - Ht_1)}{(T_2 - T_1)}
\]

Where GR=Growth Rate; dHt = differences in plant heights \((Ht_2 - Ht_1)\) between two sampling dates, and dT= date interval between 2 sampling dates, \((T_2 - T_1).\)

Results of the ANOVA on Plant Growth Rate revealed that the factors “Treatment”, “Date” and their interaction “Treatment x Date”, all had significant effects (P< 0.05) on Green Bean Plant Growth Rate. The conventional method of soil preparation (CM) resulted in significantly faster (P< 0.05) average growth rate across sampling dates, compared with the
conventional method with mulching (CMM) and the direct planting method (DPM.) However, there were no significant differences in growth rates between CMM and DPM (Figure 4). Referring to Figure 1, plant height under CM was below the values of CMM during much of the study period, but the rate of increase in plant height showed the inverse (Fig. 6.) While the addition of a mulch cover promoted plant height, it did not stimulate the rate of plant height increase in this study.

Contrasted with the growth pattern (Fig.2), the average growth rate across all three treatments showed a rather sigmoid pattern (Fig.5); the rate was significantly faster (P< 0.05) between 15 and 21 days after sowing than during any other period, averaging 0.87 cm/day. The average rate then decreased to 0.38 cm/day from 21 to 28 days, followed by moderate increases (0.60 and 0.58 cm/day) from 28 to 35 and 35 to 42 days, respectively, before slowing to an average low of 0.31 cm/day between 42 and 49 days after sowing. These results show that plant height measurements were initiated at the stage of maximum plant growth rate, 15-21 days after sowing, when green bean plants averaged 7 to 12 cm in height. We suggest from these results that for a better assessment of growth rate of green bean plants throughout the growth period, plants heights measurements should begin at an earlier stage than 15 days after sowing.
Figure 5: Average plant growth rate across all treatments per sampling date

The rate reduction observed between 21 and 28 days could be related to developments within the plant such as changes in resources allocation to other structures or functions (root growth/elongation; increases in stem diameter, leaf differentiation, flowering initiation, etc.) as opposed to their allocation for stem elongation, during this phase of plant growth. In fact, inflorescence was observed 38 DAS in each treatment and at a time when growth rate had relatively stabilized to 0.58-0.60 cm/day. Furthermore, the lowest rate in plant height increases observed between 42 and 49 days took place during the periods when the green bean plants had already reached the pod production stage. Earlier plant growth studies reported that maize plants showed no change in dry weight for the first 20 days or so of growth, and then the plant actually loses weight until about 20 days have passed (Hunt, 1978). Such growth patterns may also occur in legume crops like green beans, and even though the present study treats plant growth in terms of plant height as opposed to weight or biomass accumulation (Suk et al. 2011), there is a probable correlation between plant biomass accumulation and plant height patterns. Further studies are necessary to better ascertain the effects of both internal development and environmental factors (radiation, temperature, etc.) on green bean plants grown under edaphic-climatic conditions of the district of Vilanculos.

Pairwise comparisons of growth rates among treatments showed that the average rate under CM was higher than the rates under CMM and DPM during the first 42 days, before slowing to the rate of CMM towards the end of the study period. The DPM resulted in the lowest rate of height increase through the initial 28 days, and then increased to surpass CMM from 35 to 49 days after sowing. The overall low rate of increase in plant height under DPM at the onset
of the study period could be a reflection of green bean plants’ inability to develop deeper root systems during the earlier phases of growth in compacted soils. Soil compaction reduces water infiltration, delays germination, favors water drainage and reduces crop productivity (KUNZ et al, 2013).

Figure 6: Average growth rate per treatment, per date

![Average growth rate per treatment, per date](image)

Green Bean Pods
Summarized in Table 4 are data for the average number of green bean pods (NP), average length of green bean pods (LP), average weight of green bean pods (WP), and yield of green bean pods (YP). Significant differences (P<0.05) were observed between treatments in relation to the number of green bean pods (NP) per plant. The conventional method of soil preparation resulted in significantly higher average number of green bean pods (10.90) compared with the direct planting method with 7.30 pods per plant. However, the number of green bean pods under the CMM was not significantly different from neither CM nor DPM. On the other hand, the different methods of soil preparation had no significant effects on LP, WP and YP. However, the CMM resulted in slightly longer bean pods, while the CM resulted in slightly heavier pods and slightly better yield. The non-significant effects of the different methods of soil preparation on LP, WP, and YP under this study corroborate previous findings that soil preparation methods have no effect on green bean production, especially during the first season of growth (MULLINS et al 1988; and LANDERS, 1995.)

Although the addition of mulch does not appear to have a significant effect, the above results suggest that the conventional method of soil preparation enabled the plants to better utilize the resources available for their growth and development. In agreement with IDO E
OLIVEIRA (s/d), revolving the soil increases the mineralization of the organic components by soil microorganisms, making the soil minerals readily available to the plants. The direct planting method on the other hand, restricts plant rooting to the superficial soil layer, thus limiting plant access to the resources available in the subsurface layers.

Table 4: Multiple comparison for number of green bean pods (NP) per plant, average length of green bean pods (LP), average weight of green bean pods (WP), and yield estimate of green bean pods (YP).

<table>
<thead>
<tr>
<th>SOIL PREPARATION METHODS</th>
<th>VARIABLES</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NP</td>
<td>LP (cm)</td>
<td>WP (g)</td>
<td>PY (ton/ha)</td>
</tr>
<tr>
<td>CM</td>
<td>10.90 a</td>
<td>11.08 a</td>
<td>3.78 a</td>
<td>2.51 a</td>
</tr>
<tr>
<td>CMM</td>
<td>9.20 ab</td>
<td>11.13 a</td>
<td>3.38 a</td>
<td>1.92 a</td>
</tr>
<tr>
<td>DPM</td>
<td>7.30 b</td>
<td>10.35 a</td>
<td>3.35 a</td>
<td>1.51 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column are not significantly different @ P=0.05.

Correlation between variables is a measure of the degree to which variables change or vary together; it assumes that a linear relation exists between variables. In the present study, correlations were computed to determine whether a relation exists between Yield of green bean pods (YP) and the following variables: weight of bean pods (WP); length of bean pods (LP); and number of pod per plant (NP), and the results are presented in Table 5, below.

Table 5. Pearson correlation between pod yield (YP) and pod weight (WP); YP and length of pods (LP); and between YP and number of pods per plant (NP)

<table>
<thead>
<tr>
<th>Correlation between variables</th>
<th>Correlation coefficient (r)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>YP (Weight of Pods)</td>
<td>WP</td>
<td>0.82</td>
</tr>
<tr>
<td>YP (Length of Pods)</td>
<td>LP</td>
<td>0.75</td>
</tr>
<tr>
<td>YP (Number of Pods)</td>
<td>NP</td>
<td>0.66</td>
</tr>
</tbody>
</table>

The correlation between variables is determined by the value of the correlation coefficient (r) and the closer r is to 1, the perfect correlation, or a functional relation exists between two variables. Table 5 shows closer correlation between Yield and Weight and to lesser extents, correlations between Yield and Length of Pods as well as Yield and the Number of Pods per plant.
Conclusion
Results from this study derive from a single cropping experiment from July through September 2016, but provide valuable baseline information for future studies on growth and development of green beans in the district of Vilanculos, Mozambique. The conventional method of soil preparation with the addition of a mulch layer (CMM) resulted in better germination, and better plant height during the early phases of green bean growth, but the rate of plant height increases was significantly faster under the conventional method (CM). The addition of mulch created a better environment for seed germination, and promoted plant elongation (height), but did not stimulate the rate of increase in plant height. Further analyses of the results suggest that to better ascertain the growth pattern of green bean plants, height measurements should start earlier than 15 days after sowing, and continue at 7 day-intervals until at least 56 days after sowing. The CM also resulted in slightly higher number of bean pods per plants, and average weight of green bean pods. The different methods of soil preparation had no significant effect neither on the length of green beans, nor on the total bean crop yield. Overall, yield of green beans is rather a function of the weight and length of bean pods, but has little correlation with the number of green pods produced per plant. As reported by CAVANE et al, (2014) mulching impacts on soil structure and enhances soil fertility after 2 to 3 or more years following its application and this may explain some of the non-significant differences observed among treatments in this study.

Green bean is a plant more adapted to the tropical and subtropical areas with favorable climatic conditions for its development. However, given the increasing interest in green-bean production in the district of Vilanculos where the soils are predominantly sandy to sandy-loam and precipitation patterns erratic, there is a definite need for further experiments to complement the results of the present study. Additional studies on soil preparation methods should consider multiple cropping seasons, long-term mulching, resource allocation, as well as photosynthesis and water use efficiency throughout the growth phases of green bean plants. Such studies are important to further our understanding of the growth and development patterns of this important legume, for its sustainable production in the district of Vilanculos, in Mozambique and elsewhere.

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