EFFECT OF PLANT POPULATION ON CHARACTER EXPRESSION OF FIVE MUNGBEAN GENOTYPES UNDER DIFFERENT SOIL FERTILITY

Abdullah Taufiq1 and Afandi Kristiono

Indonesian Legumes and Tuber Crops Research Institute
Indonesian Agency for Agricultural Research and Development
Jl. Raya Kendalpayak Km 8 Po Box 66 Malang East Java 65101 Indonesia
1 Corresponding author E-mail: ofic_rilet@yahoo.com

Received: September 10, 2015 /Accepted: May 18, 2016

ABSTRACT

Plant density and soil fertility are two components of micro environment affecting genetic expression. The research was conducted at Muneng Experiment Farm in Probolinggo from March to May 2013. Two factors consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of plant population (200,000, 333,333 and 500,000 plants ha−1) were evaluated at two soil fertility treatments (with and without fertilization). The treatments were arranged in split plot design and replicated three times. All growth parameters observed were higher in more fertile soil. The increasing plant population triggered plants to grow taller, but reduced chlorophyll content index (CCI), number of trifoliate leaf per plant (LN), leaf area per plant (LA), total dry matter per plant (TDM), number of pods and seed weight, and nutrient uptake of individual plant. Grain yield production per unit area was not significantly different because of plant population compensation. All genotypes tested were suitable to be planted on population of 200,000 and 333,333 plants ha−1. With proper fertilization and population management, the genetic potential can be expressed by 3.5 t ha−1 for MMC554d-GT-2, 2.4 t ha−1 for MMC601f-GT-1 and Vima-1, 2.2 t ha−1 for MMC679-2C-GT-2, and 2.3 t ha−1 MMC647d-GT-2.

Keywords: mungbean; population; soil fertility

INTRODUCTION

Genetics and environmental interaction determine crop productivity. Sunlight, water availability, nutrients and temperature are environmental factors that influence the plant growth. Interaction between adjacent plant in utilizing environmental factors, especially sunlight, water and nutrients affect crop productivity. Adverse effect of interaction between individual plants can be minimized by proper crop and soil management.

Mungbean productivity in farmer level management during the last five years (2008-2012) was 1.1 to 1.2 t ha−1 (Ministry of Agriculture, 2012), even though potential yield of mungbean varieties released is 1.5-2.5 t ha−1 (ILETRI, 2012). Yield gap between potential and actual yield can be minimized through good management practices.

Grain yield production is determined by genetic potential, plant population (Mansoor, Khan, Ayaz, Zubair, & Nadim, 2010) and fertilizer management (Hussain, Baloch, Yang, Sanaullah, & Bashir, 2014). High potential yield of genotype is characterized by the large of leaf area and high biomass accumulation (Mondal, Hakim, Juraimi, Azad, & Karim, 2011). However, plants require adequate space to grow in a population. In accordance with plant population, proper plant spacing management has an important role in maximizing yield (Ahamed, Nahar, Rahmanullah, Faruq, & Alamgir, 2011; Kabir & Sarkar, 2008) because it affects the degree of competition between individual plant to access potential capacity of land such as light, water and nutrient. High plant population increases competition between plant and reduce occupation of plant to get light, water and nutrient. Individual plant at low population produce more branch and pod, but number of pod per unit area become low so therefore reduce yield (G. Singh et al., 2003) as well as less efficient in land use (Sullivan, 2003).

Mungbean yield decreases as plant population density increases, while the number of pods per plant decreases as population decreases. Yield per unit area generally increases as population density increase to certain level near upper limit. Optimum population of mungbean
varies over location. The highest grain yield in Punjab, India attained at population of 40 plants per m² with a spacing of 25 × 10 cm (G. Singh et al., 2011), at AVRDC, Taiwan obtained in a population of 20 plants per m² at a spacing of 50 × 10 cm, and 30 plants per m² in Bangladesh (Hossain, Ali, & Uddin, 2011), 25 plants per m² in Iran (Rafiei, 2009). Mungbean in Pati, Central Java produces better growth parameters at spacing of 30 × 30 cm rather than 30 × 20 cm (Budiastuti, 2000).

The aim of this research was to study the response of five genotypes of mungbean with different agronomic characters to different plant population and land fertility.

**MATERIALS AND METHODS**

The research was conducted at Muneng Experiment Farm in Probolinggo (7°48'06.4" S; 113°09'41.5" E; altitude 10 m asl). The seed sowed at March 15th and harvested at May 17th 2013. Materials used in the research were mungbean seed of MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1, Vima-1, inorganic fertilizer and organic fertilizer. Phonska (15-15-15) and SP36 (36% P₂O₅) use as source of inorganic fertilizer, while Petroganik use as source of organic fertilizer. Agronomic characteristic of mungbean genotypes presented in Table 1.

Two factors trial consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of plant population (200,000, 333,333 and 500,000 plants ha⁻¹) were evaluated at two soil fertility managements (with and without fertilization). Population treatment of 200,000, 333,333 and 500,000 plants ha⁻¹ obtained by dibing seed with 40 cm interrow and 25 cm, 15 cm and 10 cm between plant holes in the row, two

<table>
<thead>
<tr>
<th>No</th>
<th>Genotypes</th>
<th>Flowering (day)</th>
<th>Maturity (day)</th>
<th>Reproductive phase (day)</th>
<th>Plant height (cm)</th>
<th>Seed weight (g 100 seeds⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MMC679-2C-GT-2</td>
<td>32</td>
<td>50</td>
<td>19</td>
<td>46.4</td>
<td>5.59</td>
</tr>
<tr>
<td>2</td>
<td>MMC647d-GT-2</td>
<td>35</td>
<td>51</td>
<td>17</td>
<td>65.8</td>
<td>5.63</td>
</tr>
<tr>
<td>3</td>
<td>MMC554d-GT-2</td>
<td>36</td>
<td>54</td>
<td>18</td>
<td>75.6</td>
<td>5.97</td>
</tr>
<tr>
<td>4</td>
<td>MMC601f-GT-1</td>
<td>36</td>
<td>53</td>
<td>17</td>
<td>69.4</td>
<td>6.59</td>
</tr>
<tr>
<td>5</td>
<td>VIMA-1</td>
<td>34</td>
<td>51</td>
<td>17</td>
<td>47.1</td>
<td>6.40</td>
</tr>
</tbody>
</table>
Table 2. Soil chemical properties at different fertilization treatment

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method</th>
<th>0-20 cm</th>
<th>20-40 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH-H2O</td>
<td>1:5</td>
<td>L1</td>
<td>L2</td>
</tr>
<tr>
<td>N total (%)</td>
<td>Micro Kjeldahl</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>C-organic (%)</td>
<td>Kurmis</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>P (ppm P2O5)</td>
<td>Bray 1 extraction</td>
<td>1.28</td>
<td>1.50</td>
</tr>
<tr>
<td>K (me 100g⁻¹)</td>
<td>1 N NH4-asetat pH 7 extraction</td>
<td>30.84</td>
<td>51.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.83</td>
<td>2.21</td>
</tr>
</tbody>
</table>

Remarks: 1) L1 = check (no fertilization); L2 = fertilization at rate of 37.5 kg N ha⁻¹ + 73.5 kg P₂O₅ ha⁻¹ + 37.5 kg K₂O ha⁻¹ + 5 t ha⁻¹ Petroganik

RESULTS AND DISCUSSION

Climatic Condition
Rainfall during the emergence and early growth was very high (306 mm), and declined to 80 mm on April and 56 mm on May. Total rainfall at trial site during crop growth (63 DAP) was 442 mm (Figure 1), in the range of optimum in crop rain for mungbean (300-500 mm). There was no water stress during crop growth. The average maximum (31-32°C) and minimum (25°C) temperature was relatively constant (Figure 1), and in the range of optimum for mungbean growth (27-30°C). Total of heat unit of five genotype evaluated from sowing to harvesting was about 1,140 degree days (base temperature 10°C).

Soil Fertility
Fertilization treatment (L2) improved soil fertility in the topsoil (0-20 cm) as indicated by the increasing of soil pH by 0.1 unit, C-organic by 20%, and N, P, K content consecutively by 17%, 68% and 166% compared with check (L1) (Table 2). Soil fertility in the subsoil (20-40 cm) did not change that indicated no nutrient downward movement from the topsoil. The result showed that fertilization treatment generated different soil fertility condition as expected.

Growth Parameter
Plant height, chlorophyll content index (CCI), number of trifoliate leaf per plant (LN), leaf area per plant (LA) and total dry matter per plant (TDM) significantly affected by fertilization, plant population and genotype treatment, but no significant interaction effect among the three factors. Plant height, CCI, LN and LA were higher on fertilized plot (L2) than on check (L1). Fertilization increased plant height by 8-13%, CCI by 1-6%, LN by 14-16% (Table 3). The result indicated that characters expression of genotype tested differ at different soil fertility, and they were well expressed when grow on better soil fertility.

Plant height increases as plant population increases, but CCI, LN, LA and TDM reduce. Plant grows tallest at population of 500,000 plants ha⁻¹ and the shortest at 200,000 plants ha⁻¹. Plant height increase up to 45 DAP (pod filling stage) and then relatively constant up to harvesting time (Figure 2). CCI decreases as plant population increases. The highest CCI and LA recorded on mungbean genotypes grow on plant population of 200,000 plants ha⁻¹ and the lowest one on population of 500,000 plants ha⁻¹ (Table 3).
Table 3. Effect of fertilizer and plant population on plant height, chlorophyll content index, number of leaf, and leaf area of mungbean

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Chlorophyll content index</th>
<th>Number of trifoliate leaf/plant</th>
<th>Leaf area at 45 DAP (cm²) plant⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35 DAP</td>
<td>45 DAP</td>
<td>Harvest</td>
<td>35 DAP</td>
</tr>
<tr>
<td>Fertilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>44.4 a</td>
<td>75.3 a</td>
<td>75.3 a</td>
<td>41.34 a</td>
</tr>
<tr>
<td>L2</td>
<td>50.3 b</td>
<td>85.7 b</td>
<td>85.7 b</td>
<td>41.90 a</td>
</tr>
<tr>
<td>Plant population (plant ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200,000</td>
<td>42.6 c</td>
<td>73.2 b</td>
<td>77.7 b</td>
<td>42.58 a</td>
</tr>
<tr>
<td>333,333</td>
<td>46.8 b</td>
<td>79.0 a</td>
<td>81.1 a</td>
<td>41.41 b</td>
</tr>
<tr>
<td>500,000</td>
<td>52.7 a</td>
<td>80.8 a</td>
<td>82.7 a</td>
<td>40.87 b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.15</td>
<td>3.69</td>
<td>2.67</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Remarks: Numbers in one column in each variable with the same letter means not significantly different according to LSD test at 5% level; ¹L1= no fertilization; L2= fertilizer rate 37.5 kg N ha⁻¹ + 73.5 kg P₂O₅ ha⁻¹ + 37.5 kg K₂O ha⁻¹ + 5 t ha⁻¹ Petroganik

Figure 2. Plant height of five mungbean genotypes at various plant age

The result indicates that the increasing plant population increases the degree of competition among individual plant in acquiring light, water and nutrient for the growth. Mungbean growth showed etiolation on population of 333,333 plants ha⁻¹ and 500,000 plants ha⁻¹ due to canopy over lapping, so that reduces sunlight interception to the leaf. Shading condition triggers plant to produce more auxin and other growth regulator that stimulate stem elongation (Taiz & Zeiger, 1991). The result is in accordance with Hamzah, Rosmimi, & Syamsuardi (2005) and S. P. Singh, Sandhu, Dhaliwal, & Singh (2012). Reducing LN and LA on high plant population decrease capacity of plant to absorb water and nutrients, so that inhibit plant growth and reducing yield. Yield reduction in high plant population related to the reduction in yield component due to high nutrient absorption competition (Reddy & Reddy, 2006).

Plant height, LN and LA among mungbean genotypes tested are significantly different at various observation dates, except LN and LA variable at 25 DAP. LN increase in small number up to 45 DAP, but LA reduce after 35 DAP (Figure 3) because some small leaf rise and large older leaf become senescence, means that genotypes tested has maximum LA at 35 DAP. Vima-1 and MMC679-2C-GT-2 grow shorter than the other three genotypes (Figure 2), but LA of Vima-1 is larger than the other genotypes. In contrast with MMC679-2C-GT-2 that grow as high as Vima-1, but with lowest LA. The result indicates that potential source of photosynthesis organ of Vima-1 is the highest, and MMC679-2C-GT-2 is the lowest.
Total biomass accumulation (TDM) on different genotype and plant population is significantly different at all observation date (Figure 3). TDM of five genotypes tested have similar pattern, it grows slower until 35 DAP and then grow faster as crop start to flowering and pod setting. Fifty percent of MMC679-2C-GT-2 start to flowering at 29 DAP, MMC647d-GT-2 and Vima-1 at 32 DAP, MMC554d-GT-2 and MMC601f-GT-1 at 34 DAP. MMC601f-GT-1 accumulate TDM faster and MMC679-2C-GT-2 slower then the other three genotypes. On fertilizer treated plot, TDM increased by 31-54% during active vegetative stage (25-35 DAP) and 21-25% during generative stage. TDM of MMC601f-GT-1 and MMC554d-GT-2 is the highest, and in contrast for MMC679-2C-GT-2. MMC554d-GT-2, MMC601f-GT-1 and Vima-1 have more LA, LN and TDM then the other two genotypes that indicate have better photosynthesis ability, so that they might have high potential yield. Crops with high LA index will produce high TDM (Khan & Khalil, 2010), and high TDM accumulation is one of high potential yield characteristic of mungbean genotype (Mondal, Hakim, Juraimi, Azad, & Karim, 2011).

TDM accumulation at vegetative as well as generative stages decreases as plant population increases. The highest TDM is recorded at plant population of 200,000 ha plants ha$^{-1}$ and the lowest at 500,000 plant ha$^{-1}$ (Figure 4). TDM accumulation decreases by 30% at population 500,000 plants ha$^{-1}$ that indicates unfavourable condition for optimum growth. Reducing TDM percentage is in accordance with growth stage that indicates increasing interplant competition in accruing growth resources.

Figure 3. Number of trifoliate leaf (LN) and leaf area (LA) of five mungbean genotypes at various plant age

Figure 4. Total biomass (TDM) accumulation at different mungbean genotypes and plant population densities
Table 4. Biomass partitioning of five mungbean genotypes at various plant age

<table>
<thead>
<tr>
<th>Genotype</th>
<th>25 DAP</th>
<th>35 DAP</th>
<th>45 DAP</th>
<th>At harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaf</td>
<td>Stem</td>
<td>Leaf</td>
<td>Stem</td>
</tr>
<tr>
<td>1. MMC679-2C-GT-2</td>
<td>65</td>
<td>35</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>2. MMC647d-GT-2</td>
<td>63</td>
<td>37</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>3. MMC554d-GT-2</td>
<td>64</td>
<td>36</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>4. MMC601f-GT-1</td>
<td>63</td>
<td>37</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>5. Vima-1</td>
<td>65</td>
<td>35</td>
<td>55</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 5. Relative growth rate (RGR) and nett assimilation rate (NAR) of genotypes tested

<table>
<thead>
<tr>
<th>Genotype</th>
<th>RGR (g plant⁻¹ day⁻¹)</th>
<th>NAR (g cm⁻² day⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25-35 DAP</td>
<td>35-45 DAP</td>
</tr>
<tr>
<td>1. MMC679-2C-GT-2</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>2. MMC647d-GT-2</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>3. MMC554d-GT-2</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>4. MMC601f-GT-1</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>5. Vima-1</td>
<td>0.13</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Biomass partitioning of genotypes tested more accumulate to leaf during vegetative stage (35 DAP), to leaf and stem in similar amount during pods setting (45 DAP) and to pods during pod filling stage up to harvest (Table 4). Pods biomass percentage of MMC679-2C-GT-2 at 45 DAP is higher than the other genotypes that indicates pods development is faster due to earlier flowering date. Vima-1 has the highest pods biomass percentage at harvest that indicates high photosynthesis efficiency.

Relative growth rate (RGR) and nett assimilation rate (NAR) of genotypes tested have similar pattern. RGR is a parameter to indicate the ability of crop to produce dry matter at certain time. NAR is a parameter to indicate the ability of crop to produce dry matter per unit area of leaf at certain time. RGR and NAR increase during vegetative stage and tend to decline up to harvesting date (Table 5). This result indicates that maximum growth rate occurred during vegetative stage and then declines rapidly at pod filling stage until harvest. NAR also increased until the end of vegetative stage (35 DAP) and then reduced due to increasing effect of interplant shading. NAR of genotypes tested have negative value during period of flowering to pods setting (35-45 DAP), and plant in this period need more energy through respiration process. LPR of MMC647d-GT-2 and MMC554d-GT-2 genotypes is 8% higher than the other three genotypes at 25 DAP to 35 DAP, but LPR Vima-1 is 13% higher than the other genotypes at 35 DAP to 45 DAP and therefore Vima-1 has smallest negative value of NAR in the same period.

Grain Yield and Yield Component

Plant population, genotype and fertilization significantly affected number of branches and filled pods, dry weight of pods and grain, and harvest index. Significant interaction effect only observed between population and fertilization to number of branches and filled pods (Table 6). Plants have more branches and pods on a more fertile environment as result of fertilization treatment in all plant populations tested, except the number of branches in the treatment population of 500,000 plants ha⁻¹. The increasing plant populations decreases the number of branches and pods on both fertilized or without fertilizer treatment (Table 6). Number of pods at 333,333 and 500,000 plants ha⁻¹ respectively decreased by 29% and 47% compared to the population of 200,000 plants ha⁻¹. This suggests that the effect of plant population greater than fertilization.

Weight of pods and seeds per plant decreases by 29% and 50% as plant population increases from 200,000 plants ha⁻¹ to 333,000 and 500,000 plants ha⁻¹, respectively (Table 7). Although the yield results components of individual plant falls down due to an increase in plant population up to 500,000 plants ha⁻¹, but the productivity of grain yield per unit area is not significantly different.

Although the yield components results of individual plant falls down due to an increase in
plant population up to 500,000 plants ha\(^{-1}\), but the productivity of grain yield per unit area is not significantly different because it compensates by number of plants. These results showed that all genotypes can be planted in the population of 200,000 to 333,333 plants ha\(^{-1}\).

Table 6. Effect of plant population on number of branches and filled pods of mungbean

<table>
<thead>
<tr>
<th>Population (plant ha(^{-1}))</th>
<th>Number of branches plant(^{-1})</th>
<th>Number of filled pods plant(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1(^{1})</td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td>200,000</td>
<td>1.1 b</td>
<td>1.8 a</td>
</tr>
<tr>
<td>333,333</td>
<td>0.2 d</td>
<td>0.5 c</td>
</tr>
<tr>
<td>500,000</td>
<td>0.0 d</td>
<td>0.1 d</td>
</tr>
<tr>
<td>CV (%)</td>
<td>0.3</td>
<td>1</td>
</tr>
</tbody>
</table>

Remarks: Numbers in one column in each variable with the same letter means not significantly different according to LSD test at 5% level; \(^{1}\)L1= no fertilization; L2= fertilizer rate 37.5 kg N ha\(^{-1}\) + 73.5 kg P\(_2\)O\(_5\) ha\(^{-1}\) + 37.5 kg K\(_2\)O ha\(^{-1}\) + 5 t ha\(^{-1}\) Petroganik; \(^{2}\)number in the brackets is percentage to population treatment of 200,000 plants ha\(^{-1}\).

Table 7. Effect of fertilization and plant population on yield and yield components of mungbean

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weight of dry filled pods (g plant(^{-1}))</th>
<th>Weight of dry grain (g plant(^{-1}))</th>
<th>Weight of dry grain m.c 12% (g plant(^{-1}))</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilization</strong> (^{1})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>10.5 a</td>
<td>7.2 a</td>
<td>2.4 a</td>
<td>0.38 a</td>
</tr>
<tr>
<td>L2</td>
<td>12.1 b</td>
<td>8.1 b</td>
<td>2.3 a</td>
<td>0.34 b</td>
</tr>
<tr>
<td><strong>Plant population (plant ha(^{-1}))</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200,000</td>
<td>15.7 a</td>
<td>10.5 a</td>
<td>2.3 a</td>
<td>0.37 a</td>
</tr>
<tr>
<td>333,333</td>
<td>11.0 b (30)(^{1})</td>
<td>7.5 b (29)</td>
<td>2.5 a</td>
<td>0.37 a</td>
</tr>
<tr>
<td>500,000</td>
<td>7.3 c (54)</td>
<td>5.0 c (52)</td>
<td>2.3 a</td>
<td>0.35 b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>0.8</td>
<td>0.6</td>
<td>12.1</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Remarks: Numbers in one column in each variable and each treatment with the same letter means not significantly different according to LSD test at 5% level; \(^{1}\)L1= no fertilization; L2= fertilizer rate 37.5 kg N ha\(^{-1}\) + 73.5 kg P\(_2\)O\(_5\) ha\(^{-1}\) + 37.5 kg K\(_2\)O ha\(^{-1}\) + 5 t ha\(^{-1}\) Petroganik; \(^{2}\)number in the brackets is percentage to population treatment of 200,000 plants ha\(^{-1}\).

Table 8. Yield and yield component of mungbean genotypes tested

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Number of branches per plant</th>
<th>Number of filled pods per plant</th>
<th>Weight of dry filled pods (g plant(^{-1}))</th>
<th>Weight of dry grain (g plant(^{-1}))</th>
<th>Weight of dry grain m.c 12% (g plant(^{-1}))</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MMC679-2C-GT-2</td>
<td>0.5 b</td>
<td>14 a</td>
<td>9.8 c</td>
<td>6.7 c</td>
<td>2.2 c</td>
<td>0.37 ab</td>
</tr>
<tr>
<td>2. MMC6847d-GT-2</td>
<td>0.4 b</td>
<td>14 a</td>
<td>11.3 b</td>
<td>7.6 b</td>
<td>2.3 bc</td>
<td>0.34 c</td>
</tr>
<tr>
<td>3. MMC554d-GT-2</td>
<td>0.6 b</td>
<td>14 a</td>
<td>11.3 b</td>
<td>7.5 bc</td>
<td>2.5 a</td>
<td>0.37 ab</td>
</tr>
<tr>
<td>4. MMC601f-GT-1</td>
<td>0.5 b</td>
<td>13 a</td>
<td>11.1 b</td>
<td>7.8 ab</td>
<td>2.4 ab</td>
<td>0.35 bc</td>
</tr>
<tr>
<td>5. Vima-1</td>
<td>1.0 a</td>
<td>15 a</td>
<td>13.1 a</td>
<td>8.6 a</td>
<td>2.4 ab</td>
<td>0.39 a</td>
</tr>
</tbody>
</table>

Remarks: Numbers in one column in each variable with the same letter means not significantly different according to LSD test at 5% level.
Grain yield and yield components are significantly different among genotypes, except number of filled pods (Table 8). Grain yield of MMC554d-GT-2, MMC601f-GT-1 and Vima-1 is significantly higher than MMC679-2C-GT-2 and MMC647d-GT-2. The higher grain yield of MMC554d-GT-2 and Vima-1 probably related to high effectiveness and efficiency of photosynthesis as indicated by higher LN, LA and biomass partition to the seed. The higher grain yield of MMC601f-GT-1 probably related to bigger seed size. Vima-1 has the highest harvest index (HI) that indicates high photosynthesis efficiency. The result showed that genotype with high TDM accumulation and LA tends to have high yield, and this is in accordance with Ahmed, Hirota, Yamada, & Rahman (2003), Sharma-Natu & Ghildiyal (2005), Mondal, Fakir, Islam, & Samad (2011), Malek, Mondal, Ismail, Rafii, & Berahim (2012). HI of all genotypes tested ranged from 0.34 to 0.39, and this is little bit higher than that reported by Thomas, Robertson, Fukai, & Peoples (2004) which is 0.3.

### Nitrogen, Phosphorous and Potassium Uptake

Fertilization treatment increases nitrogen (N), phosphorous (P) and potassium (K) uptake in the leaf and stem. N, P and K uptake in the leaf at the end of vegetative stage (35 DAP) increased by 33%, 32% and 23%, respectively, while in the stem increased consecutively 47%, 29% and 56% compared with that of no fertilization (Table 9). As much as 77% of N and 62% of P are accumulated in the leaf, while 61% of K accumulated in the stem (Table 10). Higher N accumulation in the leaf may be related to the function as part of chlorophyl component. Nitrogen is the main constituent element of amino acids and lipids forming the chloroplast, and element of rubisco enzyme (25-30% of total N) that has important role in photospiration (Ouda & Mahadeen, 2008). Higher K accumulation in the stem may be related to the role in nutrient and assimilate translocation.

Table 9. N, P and K uptake on mungbean genotype at the end of vegetative stage (35 DAP)

<table>
<thead>
<tr>
<th>Fertilization&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Uptake in the leaf (mg plant&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Uptake in the stem (mg plant&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>L1</td>
<td>143.4</td>
<td>12.6</td>
</tr>
<tr>
<td>L2</td>
<td>191.1</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Remarks: <sup>1)</sup>L1= no fertilization; L2= fertilizer rate 37.5 kg N ha<sup>-1</sup> + 73.5 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> + 37.5 kg K<sub>2</sub>O ha<sup>-1</sup> + 5 t ha<sup>-1</sup> Petroganik

Table 10. N, P and K content in the leaf and stem of mungbean genotype at the end of vegetative stage (35 DAP) at different fertilization and plant population treatments

<table>
<thead>
<tr>
<th>Population (plants ha&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Nutrient content (%)</th>
<th>Leaf</th>
<th></th>
<th>Stem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1&lt;sup&gt;1&lt;/sup&gt;</td>
<td>L2</td>
<td>L1</td>
<td>L2</td>
</tr>
<tr>
<td>200,000</td>
<td>4.48</td>
<td>4.68</td>
<td>0.40</td>
<td>0.41</td>
</tr>
<tr>
<td>333,333</td>
<td>4.63</td>
<td>4.63</td>
<td>0.39</td>
<td>0.40</td>
</tr>
<tr>
<td>500,000</td>
<td>4.24</td>
<td>4.49</td>
<td>0.38</td>
<td>0.39</td>
</tr>
<tr>
<td>Average</td>
<td>4.45</td>
<td>4.60</td>
<td>0.39</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Remarks: <sup>1)</sup>L1= no fertilization; L2= fertilizer rate 37.5 kg N ha<sup>-1</sup> + 73.5 kg P<sub>2</sub>O<sub>5</sub>ha<sup>-1</sup> + 37.5 kg K<sub>2</sub>O ha<sup>-1</sup> + 5 t ha<sup>-1</sup> Petroganik

Five genotypes tested have the same response to an increase in soil fertility which grew higher, had more leaf number, leaf area, biomass accumulation, chlorophyll content, number of pods and seed weight. The increasing plant population from 200,000 plant ha<sup>-1</sup> to 333,333 plants ha<sup>-1</sup> and
500,000 plants ha\(^{-1}\) induced crops grow taller, but reduced number of leaf, leaf area, chlorophyll content, and biomass accumulation due to the increasing interplant competition for light and nutrients. Increasing nutrient competition at high plant population could be minimized by fertilization. Number of pods and seed weight reduced by 30\% every 50-60\% of population increased, even though grain yield productivity was not affected by compensation between yield component and plant population. The five genotypes tested are suitable planted on population of 200,000 and 333,333 plants ha\(^{-1}\). With proper fertilization and population management, the genetic potential can be expressed as follow 3.5 t ha\(^{-1}\) for MMC554d-GT-2, 2.4 t ha\(^{-1}\) for MMC601f-GT-1 and Vima-1, 2.2 t ha\(^{-1}\) for MMC679-2C-GT-2 and 2.3 t ha\(^{-1}\) for MMC647d-GT-2.

ACKNOWLEDGMENT
The authors would like to thanks to Mr. Salam for his helpful assistance in the research.

REFERENCES


