Compost effects on leaf area index and seed production enhancement in an important arid land leguminous tree (Acacia tortilis subsp. Raddiana)

A.A. Elfeel* and R.A. Abohassan

Department of Arid land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia.

Received: 25-01-2016 Accepted: 15-07-2016 DOI:10.18805/lr.v0iOF.3546

ABSTRACT

This study aimed to investigate the effects of compost addition on leaf area index (LAI), diameter growth and enhancement of seed production and quality in Acacia tortilis established under supplementary drip irrigation. Three composted fertilizer doses (2.5 kg, 5 kg and 7.5 kg/tree) were compared to NPK (18-18-5 at a rate of 250 gram per tree) and control unfertilized plots. Effects of compost application on leaf area index (LAI), diameter growth, relative monthly diameter increment (RMDI) were monitored during two consecutive years (2014 and 2015). Then the impacts on pods and seeds production, seed weight, seed number per kg, seed quality (NPK and protein), germination per cent and mean germination time (MGT) were determined. Addition of fertilizers produced high effects on LAI. In 2014 NPK resulted in highest LAI values in most measurements, alternatively the status was changed in 2015 where, higher doses of compost produced higher LAI values. LAI results exhibited temporal variability that was associated with the seasonal variation of the year. The results demonstrate higher RMDI and diameter growth under NPK and compost at rate of 7.5 kg/tree treatments. Pods production was higher in plots treated with higher doses of compost. However, seed/husk ratio was higher in NPK plots. There is observed association between fruit and seed production with LAI. NPK and protein contents in seeds, were also, influenced by the presence of organic fertilizers. Cumulative germination and MGT were correlated with seed weight and were higher in plots treated with compost. The results highlight the importance of organic fertilizers under dry land conditions that produced higher LAI and growth which enhanced seed production and quality.

Key words: Compost, Leaf area index, Mean germination time, Relative monthly Diameter increment, Seed production, Seed quality.

INTRODUCTION

Both forestland and other wooded land represent very small area compared to total land area of Kingdom of Saudi Arabia (FAO, 2015). Therefore, the main target of the national forest strategy formulated in the year 2002 is to maintain existing forest areas and add more plantations with suitable adaptable species (Anonymous 2002). To meet these intended expansions in forest plantation it is necessary to provide seeds with high physiological and genetic qualities that will adapt to the planting seed zones and future climatic fluctuations (Potter and Hargrove, 2012). Under arid lands with little or no rainfall, seed production from natural trees is minimal. Leguminous tree species have a high potential association with many different groups of vegetation (El-Ghanim et al., 2010). The occurrence of the A. tortilis has positive effects on the underground vegetation (Abdallah et al., 2012) and protects the soil in degraded grazing areas (Fierich et al., 2012). In addition to that leaves from this tree contain some medicinal values (Dakhelallah and Alharbi, 2015).

The reduced rainfall in most parts of the dry lands of KSA, especially the Western region affected seed production in natural forest areas. In addition to that, the seeds produced naturally where heavily infested by bruchid beetles in such a way that there is a lack of new regeneration from the local seed banks (Wahbi et al., 2013). The beetles lay their eggs in the green pods; complete its life cycle inside the seed then, the mature adult exit the seed through the whole

*Corresponding author’s e-mail: aidris@kau.edu.sa and address: Department of Arid land Agric., King Abdulaziz University, P.O.Box 80208, code 21589, Jeddah, Saudi Arabia.
in the seed (Derbel et al., 2007). To improve germination in *Acacia tortilis* seeds it is necessary to pretreat the seeds with concentrated sulfuric acid in 30–40 minutes acid duration (Elmagboul et al., 2014), or incubate the seeds in temperature (Ahmed 2008).

The application of compost has gradual multiple effects in improving soil physical and chemical properties and thus source of nutrients to the plants (Wu et al., 2013). It is also, important for mitigating \( \text{NO}_x \) emissions from the soils (Ding et al., 2013), enhances bio-stimulation, which increases soil microorganisms (Valarini et al., 2009) and increases nutrient uptake (Pane et al., 2015). The use of organic fertilizers leads to increased seed yield and seed quality contents in many plants (Jahan et al., 2008; Piraveena and Seran, 2010; Seran and Suthamathy, 2013). The LI-COR non-destructive measurement of leaf area index (LAI) is based on measurements of photosynthetically active radiation (PAR) in plants. Thus, it serves as good indicator to estimate plant yield and productivity (Jego et al., 2012). Good parameter to predict forage growth development and yield (Elfeel et al., 2013). Has positive response to addition of fertilizers (Amanullah et al., 2007).

The aim of the current study was to enhance seed production from locally planted stands of *A. tortilis* under supplementary irrigation by addition of fertilizers. The specific objectives are to investigate the effect of organic fertilization on seed quantity and quality of *A. tortilis* grown from local seed source in King Abdulaziz University Experimental Farm at Hada Al-Sham.

**MATERIALS AND METHODS**

**Study site:** The experiment was conducted during the years 2013/2014 and 2014/2015 in a mature stand of *Acacia tortilis* planted trees in the Agricultural Research Station of the King Abdulaziz University at Hada Al-Sham area. The trees were previously planted from seeds collected from local site around Hada Al-sham area in the year 2005. The planting spacing is 6 X 5 meters, thus giving about 333 trees per hectare. The Research Station is located at North-East of Jeddah City in a distance of more than 100 km.

**Experimental design:** The experimental design used was factorial complete randomized block design with three replicates and five fertilization treatments. The main treatment factors are: three organic fertilization levels (2.5 kg, 5 kg and 7.5 kg/tree), plus control unfertilized plots and NPK (18-18-5 at a rate of 250 gram per tree) fertilization to compare organic fertilization with inorganic fertilization normally applied. The manure used was Al-Morroj Compost - Rashid Bio-fertilizers Factory (3.13% total nitrogen, 40% organic matter, 5.34 C/N ratio, 16.71%, total organic carbon 1.52% P and 0.23% K on dry matter basis). In late 2013, the drip irrigation system was established. The trees were regularly watered by drip irrigation at frequency of once every 15 days. After the irrigation system was maintained; fertilizer treatments were applied. The manure was spread and thoroughly distributed around the trunk of the tree. The fertilizers were added once in the year 2014 and once in the year 2015. After addition of fertilizers irrigation was carried once every week for one month to allow manure decomposition; then after returned back to normal irrigation of every two weeks. Two trees per each treatment were used as experimental unit. Measurements were started and data collected after six months of treatments application.

**Leaf area Index (LAI) Measurements:** In each of the two years, four consecutive LAI measurements at a frequency of every two months were made using plant canopy analyzer (model 2270, LI-COR Biosciences, 2011). For every treatment, one above reading followed by two below readings was used as administered protocol to measure LAI. In both above and below readings, we reduced the full view of the sensor by using 90° viewing cap in order to make sure that all the five azimuthal angles view the same measuring tree canopy.

**Tree diameter DM growth:** Diameter growth (DM) measured four times at four months interval between the readings. The diameter was measured at one meter length along the tree bole in every measurement. When the tree is branching below one meter; diameter measurement was done for the big branch. The diameter was measured with Digital Caliper. Relative monthly diameter increment (RMDI) was calculated by the following formula: \( \text{RMDI} = (\text{DM}_{2} - \text{DM}_{1}) / (t_{2} - t_{1}) \), where DM2 is the diameter at the last month, DM1 diameter at the first month, \( t_{1} \) is the last month and \( t_{1} \) is the first month.

**Pods and seed production:** In year 2015, pods and seed yield per tree and per each treatment was determined. The pods were collected from the trees by shaking the fruit bearing branches and the pods fallen on the plastic sheet laid under the trees were collected. This was repeated two to three times until all ripe pods on the tree were collected. Pods from each tree were weighed, and then afterwards the seeds were extracted from the pods and weighed. The husk weight was determined by subtraction (pods weight – seed weight). Seed/husk ratio was calculated as seed weight divided by husk weight. Seed production (KG) per hectare for each treatment was calculated as average number of trees per hectare (333) multiplied by average yield per tree for each treatment. While for 2014 year due to low production only seed production per tree and hectare was determined.

**Seed weight and seed number per kilogram determination:** Seed weight was determined in eight replicates of 100 seeds (ISTA, 2011) while, seed number per kilogram was calculated as number of seeds in a sample * 1000/Weight of sample in gram.

**Seed NPK and protein analysis:** Nitrogen was determined by automated micro-Kjeldahl method and then Protein content
was calculated by multiplying $N$ by 6.25 (Horneck and Miller, 1998). $K$ was analyzed using atomic absorption spectrophotometry. $P$ was determined according to the method described by (Bhargava and Raghupalhi, 1993).

**Germination and mean germination time (MGT):** Seeds harvested were germinated to test their viability and germination capacity. Before performing germination test, average beetle infestation was estimated. Four samples of 50 seeds were drawn from each lot. Then seeds with beetles exit holes were counted as bruchid infested seeds. The percentage of infested seeds were calculated as (number of infested seeds*100/50 seeds sample). To carry germination test the seed samples were treated with concentrated sulfuric acid for 35 minutes and dried in septic surface. Germination trays were soaked for half an hour in 20% Clorox household bleach solution to avoid contamination of seeds by pathogens (Bicksler, 2011). Germination was done on four replicates of 100 seeds per replicated for each treatment (ISTA, 2011). Then we administered germination count for four weeks. Total cumulative germination percent was calculated as total cumulative number of seeds germinated at week four divided by the total number of seeds sown. While mean germination time (MGT) was derived by the following formula $MGT = \frac{\sum (G \times T)}{F}$ according to (Ranal et al., 2009). Where; $T =$ days from beginning of germination test, $G =$ number of seeds germinated in day $T$ and $F =$ total number of seeds germinated.

**Data analysis:** The effects of the main treatment factors were tested by ANOVA and the means were separated by new Duncan’s multiple range test using SAS (Statistical Analysis System, SAS System version 9.1, 2014).

**RESULTS AND DISCUSSION**

**Leaf Area Index (LAI):** The data shown in Figures 1a and 1b demonstrate that LAI of *A. tortilis* was highly affected by the addition of NPK and organic fertilizers compared to control unfertilized trees during the two years. These results are similar to Amanullah *et al.*, (2007) who reported direct response of LAI to fertilization. In year, 2014 NPK was resulted in significantly higher LAI values than organic fertilizers. However, the trend was changed in year 2015, where organic fertilizers at the rate of 7.5 kg/tree showed higher LAI values than NPK in most of the measurements. This explains the importance of gradual compost effects on soil and plants (Wu *et al*. 2013). Thus with time organic fertilizers can give comparable or better results relative to NPK for improving growth in this species. In addition, the results showed that both organic fertilizers at the rate of 7.5 kg/tree and NPK gave increased results compared to other organic fertilization rates and control (Table 1).

In respect to the two years, the LAI values in year 2015 were higher compared to the values in year 2014, irrespective of fertilization rate. This may be due to the increase in growth development and leafiness through time. The current data also, revealed temporal variability in LAI. This variation was associated to the season of the year. The data presented showed that in less hottest times during October-November, the LAI values were low, started increasing reaching the peak in December-January (the most coolest time of the year) and then tend to decline giving least values during the hottest times of the year (April-May). During the period between June to August, almost all the trees completely shed their leaves. This was similar, to the finding of Fanga *et al.*, (2014), who reported seasonal variability trends in LAI values. This might be explained by the fact that LAI was related to the active growing season of the year, since it measured PAR radiation in plants. That is why it was observed that direct association of LAI with tree productivity (Elfeel *et al.*, 2013) or plant growth and yield (Jego *et al.*, 2012).

**Diameter growth (DG) and relative monthly diameter increment (RMDI):** Diameter growth was significantly affected by addition of fertilizers compared to control unfertilized trees (Table 2). NPK produced significantly higher DG growth compared to higher doses of organic fertilization at the rate of 7.5 kg/tree in two measurements.
Table 1: Mean diameter growth (cm) and relative monthly diameter increment rate of *Acacia tortilis* as affected by organic fertilizer, measured during the years 2014 – 2015.

<table>
<thead>
<tr>
<th>TRT</th>
<th>Measurements</th>
<th>Diameter RMDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>NPK</td>
<td>10.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.78&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic7.5</td>
<td>10.29&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>11.28&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic5</td>
<td>10.18&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>11.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic2.5</td>
<td>9.13&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>9.41&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Control</td>
<td>9.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.05&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 2: Mean pods, seeds and husk production (kg/tree) and seed production per hectare (kg) of *Acacia tortilis* as affected by organic fertilizer, measured during the years 2014 – 2015.

<table>
<thead>
<tr>
<th>Year 2015</th>
<th>Year 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRT</td>
<td>Production (Kg/tree)</td>
</tr>
<tr>
<td>NPK</td>
<td>6.50&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic7.5</td>
<td>7.33a</td>
</tr>
<tr>
<td>Organic5</td>
<td>6.66b</td>
</tr>
<tr>
<td>Organic2.5</td>
<td>5.30c</td>
</tr>
<tr>
<td>Control</td>
<td>5.05c</td>
</tr>
</tbody>
</table>

The rate of relative monthly diameter increment was also, significantly affected by the addition of fertilizers (Table 2). Higher dose of organic fertilizers produced similar results to NPK. Both were significantly higher than control and other organic fertilization rates. In turn, the other organic fertilization rates produced higher, RDI compared to control trees. This result highlights the importance of using organic fertilizers. Although, the added effects of organic fertilizers at the beginning was low but with time it started to improve soil properties. The gradual effects of organic fertilizers reached through improved physical properties and enhancement of microorganisms of the soil (Valarini et al., 2009; Ding et al., 2013; Pane et al., 2015). This reflects their importance of use in arid soils which were characterized by poor physical properties and lacking of microorganisms.

Pods and seed production: During the first year, (2014) seed production was very low under all treatments. This might be related to the fact that the trees were not well grown for seed production in the first year. Alternatively, may be due to normal seed periodicity, a common phenomenon in Acacias. In year 2015, application of organic fertilizers resulted in significant increase in the amount of pods and seed produced per tree and hence per hectare compared to control unfertilized trees (Table 3). In turn higher rates of organic fertilizers applied obtained more or less similar results to NPK inorganic fertilization (Table 3). Compost doses at the rate of 7.5 kg per tree obtained higher pods production than NPK, but with more husks. In the other hand,
NPK produced less pods weight but with higher seed per tree compared to organic7.5 treatment. This resulted in higher seed/husk ratio for NPK. It was observed that seed and pods production were associated with LAI values of the trees. Treatments with higher LAI values obtained higher pods and seed production.

**100 seed weight, seed number per kg, NPK and protein:**
The data presented in Table 4, showed that addition of fertilizers significantly affected seed weight and seed number per kg. Organic fertilizer at the rates of 7.5 and 5 kg/tree obtained higher seed weight and hence less seed numbers per kilogram compared to the NPK, 2.5 kg/tree rate and control. Where, NPK did not statistically differ from organic fertilization at rate of 2.5 kg/tree and control.

In general, addition of fertilizers revealed higher NPK and protein contents in the seed produced compared to the control untreated plots (Table 4). However, NPK treatment showed higher values over organic fertilization on the amount of NPK and protein in the seeds.

**Germination and mean time to germinate (MTG):** Adding compost to tortilis trees under arid saline soil at the rates of 7.5 and 5 kg per tree resulted in significantly higher cumulative germination and MTG compared to other treatments (Table 4). Where NPK revealed similar trend in germination and MTG to compost at the rate of 2.5 kg/tree and control untreated trees. This result explains direct relationship between germination percent and MTG with seed weight. Treatments of 7.5 and 5 kg compost per tree that have higher seed weight obtained higher total germination and MTG, compared to other treatments. Positive correlation of germination with seed weight was observed in many studies (Elfeel and Warrag, 2004). However, this relationship was attributed to different reasons. In some species the effects on germination is related to seed coat (De souza and Marcos-Filho, 2001). In other species, higher seed weight is due to higher endosperm content. The low percentage of germination recorded is obtained as the result of high bruchid infestation. It is known that seeds from this tree have very high germination levels (Elmaboul et al., 2014). However, under similar arid conditions bruchids can destroy majority of the seeds produced while on the tree (Wahbi et al., 2013; Derbel et al. 2007). A sound method for bruchid control is highly needed since they normally infest the green pods before ripening on the tree.

**CONCLUSION**
The current study revealed that LAI was positively responsive to addition of fertilizers and seasonal variation of the year. In addition, LAI was associated with higher diameter growth, mean monthly diameter increment and fruit and seed production. Thus, LAI can be used as good indicator for measurement of growth and productivity for this species. The addition of organic fertilizers resulted in good enhancement of seed production under hyper arid conditions of western KSA. Although, the bruchids infestation affected seed viability and germination, but the seed produced from fertilized trees have good quality and better germination capacity.

**ACKNOWLEDGEMENT**
This project was funded by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah under grand No. (274/155/1434). The authors therefore, acknowledge with thanks DSR technical and financial support.

**REFERENCES**


Anon. (2002). National forest policy and implementation strategy. Ministry of Agriculture. KSA.


### Table 4: Mean borer infestation, seed germination percent and mean germination time (MGT) of *Acacia tortilis* as affected by organic fertilizer.

<table>
<thead>
<tr>
<th>TRT</th>
<th>Borer infected</th>
<th>Germination %</th>
<th>MGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK</td>
<td>33a</td>
<td>60.3c</td>
<td>8.9a</td>
</tr>
<tr>
<td>Organic7.5</td>
<td>15c</td>
<td>65.0a</td>
<td>7.8a</td>
</tr>
<tr>
<td>Organic5</td>
<td>24b</td>
<td>63.5b</td>
<td>8.4a</td>
</tr>
<tr>
<td>Organic2.5</td>
<td>16c</td>
<td>60.3c</td>
<td>9.1a</td>
</tr>
<tr>
<td>Control</td>
<td>25b</td>
<td>60.0c</td>
<td>9.1a</td>
</tr>
</tbody>
</table>

* = ≤ 0.05     ** = ≤ 0.01     ns = not significant


