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**Research Article**

# GROWTH AND YIELD OF *SORGHUM* UNDER EFFECT OF SOME *ACACIA* SPECIES PLANTATION

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## ABSTRACT

Taking into consideration the importance of agricultural production sustainability with greater resource use efficiency in arid area, field study was conducted to investigate the effect of four, Acacia trees (Acacia nilotica, Acacia seyal, Acacia senegal and Acacia tortilis) planting combination on soil and Sorghum bicolor L. The crop planted between strips of four Acacia trees (eight planting combinations). Acacia species had significantly increasing soil available nitrogen, Soil between rows of A. torilis and A. seyal has highest nitrogen content,. Increasing of soil fertility has positive effect on the Sorghum plants grown in strips between these planting combination significantly taller with more leaves with greater fresh and dry weight compared to control plants which had least growth and yield traits. Sorghum planted between rows of A. tortilis and A. seyal, and between A. senegal and A. tortilis registered highest technical efficiency. As conclusion, intercropping of sorghum with Acacia can be alternative agricultural practices in Saudi Arabia or any area with similar ecological condition to amend soil, improve crops growth, and yield performance.



## INTRODUCTION

Agroforestry plays an vital role for sustainable agriculture landscape, by giving ecological services and environmental benefits (Branca *et al*., 2013). Trees reducing the negative effects of climate and soil aridity (Anderson *et al*., 2001). Under trees canopys, the soil often contains a higher quantity of organic matter and available nitrogen for plants a good physical structure, and a better water infiltration (Smit and Swart, 1994). Several factors are associated with the improvement of the soil fertility process under canopy including the litter of herbs and dead parts of the *Acacia* trees (Amiotti *et al*., 2000). *Acacia* species in general are multipurpose trees providing a wide range of products and services (Pandey and Sharms, 2003). Agroforestry may provide a financially viable way of protecting crops in areas where microclimatic factors regularly exceed the optimal range (Lin, 2007). Conservation agriculture with trees is now emerging as the most promising land use option to sustain agricultural productivity (Syampunani *et al*., 2010). However, *Acacia* species in general are adapted to arid environment but not given much attention. Ong and Leakey (1999) concluded, woody multi-purpose and probably adapted tree species have been neglected. Sorghum ranks as fifth among the world's most important crops (Srivastava *et al*., 2010), it is a multipurpose crop which is globally used as food, feed or forage (Iqbal and Iqbal, 2015). It is adapted to a variety of agronomic and environmental conditions, particularly to areas with low rainfall or limited access to irrigation water (Getachew *et al*., 2016).The objective of this work is to investigate the effect of some legume trees, namely *Acacia* trees species plantation, on sorghum growth and performance in arid area.

## MATERIALS AND METHODS

### *Study site and Experiment Layout*

To examine the effect of four *Acacia* trees plantation on soil fertility and sorghum growth and yield, field experiment conducted in Research and Experiments Station of the Faculty of Food Sciences and Agriculture, King Saud University, located southwest of Riyadh City, Saudi Arabia. The site characterized by harsh weather -high temperature, low relative humidity and very low rainfall during cropping period July – August- (Figure 1). Experimental area of 80×90 m (0.72 ha)

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was prepared according to the aims of the experiment, and then six months old seedlings of *A. nilotica, A. senegal, A. seyal and A. tortilis* were transplanted to field. For the purpose of experiment, seedlings were planted in rows (distance between each row was 6 meter and distance between each trees was 4 m). Trees were managed by irrigating twice per aweek. The removing the lower branches, leaves and twigs were used as mulch while all woody branches were removed. After four years when trees exceed juvenile stage ( i.e. DBH > 0.5 cm) and trees plantation was established, *Sorghum bicolor* L crop sown (3-4 seeds per hole) in strips laid out between trees rows (strip area was 3×8 meter), distance between trees row and strip was 1.5 m to avoid complete shading of trees crown. Each strip contained 8 rows of sorghum plants (distance between row 40 cm). Table (1) showed description of treatments (planting combination) and strips between trees rows.

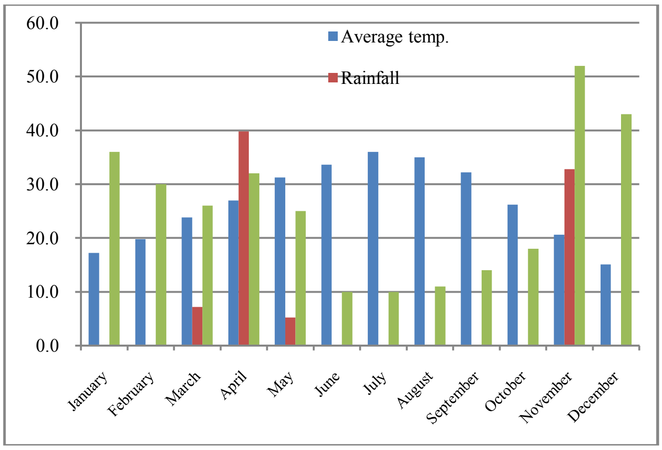


**Figure 1** Monthly average temperature, rainfall and relative humidity, Source of data : https://www.pme.gov.sa/Ar/MediaCenter/OpenData

**Table 1** Description of treatments (trees planting combination) and strips

| Strips between trees row (code) | Strip description | | | |
|---|---|---|---|---|
| | Between | width (m) | Length (m) | Area ($m^2$) |
| NS | Two rows of *A. nilotica* and *A. senegal* | 5 | 10 | 50 |
| SS | Two rows of *A. senegal* | 5 | 10 | 50 |
| ST | Two rows of *A. Senegal* and *A. tortilis* | 5 | 10 | 50 |
| TT | Two rows of *A. tortilis* | 5 | 10 | 50 |
| TSY | Two rows of *A. tortilis* and *A. seyal* | 5 | 10 | 50 |
| SYN | Two rows of *A. seyal* and *A. nilotica* | 5 | 10 | 50 |
| NN | Two rows of *A. nilotica* | 5 | 10 | 50 |
| C | Control (treeless area) | 5 | 10 | 50 |
| Total cropped area | | | | 400 |

### *Estimation and Measurements*

For estimation of soil available nitrogen, soil samples were taken at 1-30cm soil depth from strips each tree rows (planting combinations) available N in soil samples determined according to Silva *et al.*(2007). Before crop harvest, plant height and number of leaves per plant were measured during growth stage (before harvesting). After 70 days from crop sowing yield was estimated by quantifying the dry weight of each row after oven drying at 70◦c until constant weight. In order to measure the impact of this agroforestry experiment on production and productivity of sorghum, a technical efficiency is estimated using Data Envelop Analysis (DEA). Technical efficiency referred to the ability of an experimental unit to produce as large as possible output from a given set of inputs (Ali and Yousif, 2012; Yousif and Abudabos, 2013). The DEA is a non-parametric method based on a linear convex hull approach to frontier estimation (Farrell, 1957). The DEA involved the use of linear programming to construct a nonparametric piecewise surface over the data representing a production function frontier (Coelli *et al.*, 2005). The input-oriented DEA model was estimated under the assumption of constant returns to scale (CRS) of activities, this produce what is called CCR model (Banker *et al.*, 1984). The Data Envelope Analysis Program (DEAP) version 2.1 was used to construct the DEA frontiers for the calculation of technical efficiency scores of different treatments.

### *Experimental Design and Statistical Analysis*

The experiment was complete randomized design, each row between one or two species considered as treatment plus control (eight treatments). All tested parameters were analyzed by SAS, using ANOVA to test variations between trees planting combination at < 0.05. LSD test was used for mean comparison.

## RESULTS

### *Soil Available Nitrogen (N) Between Strips*

Although there was different effect of *Acacia* trees species planting combination on soil fertility, but as overall, the four species combination had significantly increasing soil fertility in terms of N as compared to bear soil (control). The highest nitrogen (59.01, 47.11, 46.54 mg kg -1) was recorded in strips between *A. seyal* and *A. tortilis*(TSY) and pure *A. senegal* (SS), and pure *A. tortilis* (TT), respectively. The lowest nitrogen content (8.75 mg kg -1) recorded in control strip (fig. 2).

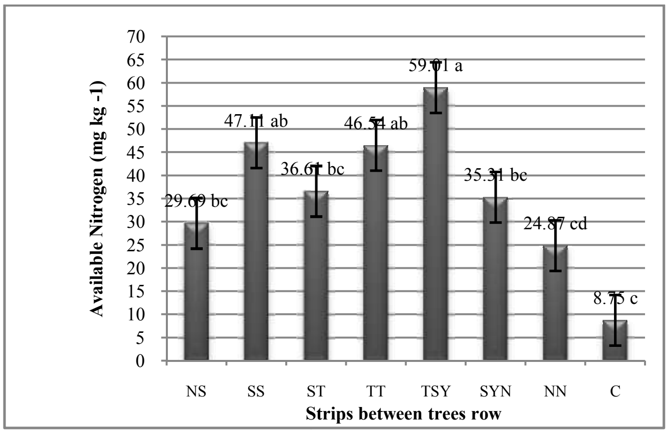


**Figure 2** Effect of *Acacia* trees on soil available nitrogen *Bars represent means. Different letters indicate significant differences between trees row combination at < .0012

### *Growth Performance of Sorghum*

The analysis of variance on studied growth traits of sorghum revealed that the four tree species significantly ($p < 0.0001$) affect Sorghum plant height and leaves number (Table 3). Mean values in Table (3) showed that the maximum plants height (168.41 cm) recorded in plants grown in strips between pure *A. Senegal* (SS) followed by crop grown between *A. seyal - A. tortilis* (TSY) and *A. niltica - A. senegal* (NS), respectively. On the other hand, control plants have a minimum height (88.75 cm). Regarding leaves number the data in Table (3) showed the same trend as height. The plants grown between pure *A. senegal* (SS), and between *A. seyal* and *A. tortilis* (TSY) and between. *Niltica* and *A. Senegal* (NS) have more leaves number compared to other plants. Control plants have a minimum leaves number.

### *Sorghum Yield Under effect Acacia trees*

The sorghum plants between different trees rows produced higher fresh and dry weight of sorghum comparing to control plants (table 3). Generally, the performance of sorghum under *Acacia* trees is higher than treeless (control). This can be attributed to increase in soil fertility and improvement of soil physical properties under *Acacia* trees as a result of addition of organic matter through litter mineralization. Sorghum grown between pure *A. Senegal* rows (SS) has a higher fresh and dry weight comparing to other system followed by sorghum grown between *A. senegal* and *A. nilotica* rows (NS), and pure A. *nilotica* rows (NN).

**Table 3** Effect of *Acacia* trees on sorghum growth

| Trees row combination | Growth parameters | |
|---|---|---|
| | Plant height (cm) | Leaves number |
| **NS** | 147.52±3.32 [b] | 12.25±1.31 [abc] |
| **SS** | 168.41±4.19 [a] | 12.83±1.46 [a] |
| **ST** | 135.16±2.80 [c] | 11.05±1.54 [cd] |
| **TT** | 147.52±3.48 [b] | 10.25±1.69 [de] |
| **TSY** | 156.60±4.45 [ab] | 12.50±0.78 [ab] |
| **SYN** | 153.60±3.16 [b] | 11.00±1.03 [cd] |
| **NN** | 134.83±2.59 [c] | 11.25±1.26 [bcd] |
| **C** | 88.75±3.57 [d] | 8.92±1.20 [e] |
| ***P*-value** | < 0.0001 | <0.0003 |
| **LSD** | 12.097 | 1.6455 |

**Table 3** Effect of *Acacia* trees on sorghum yield

| Trees row combination | Yield parameters | |
|---|---|---|
| | Fresh weight (Kg$^{-1}$ m$^2$) | Dry weight(Kg$^{-1}$ m$^2$) |
| **NS** | 58.16±3.39[b] | 16.32±1.78 [bc] |
| **SS** | 79.70±2.81[a] | 29.86±1.47 [a] |
| **ST** | 46.29±2.85 [bc] | 14.76±1.20 [bc] |
| **TT** | 43.73±2.27 [bc] | 13.54±0.94 [cd] |
| **TSY** | 41.96±1.95 [cd] | 12.65±1.48 [cd] |
| **SYN** | 54.50 ±2.73[bc] | 12.77±1.10 [cd] |
| **NN** | 58.16±1.91 [b] | 20.87±1.36 [b] |
| **C** | 27.53±1.69 [c] | 7.66±0.72 [d] |
| ***P*-value** | <0.0001 | <0.0001 |
| **LSD** | 14.99 | 6.4380 |

### *Technical Efficiency of Sorghum Grown Under Acacia trees Combination*

The technical efficiency score lies between one and zero, the greater the score means the higher efficient use of resources and vice versa. Table (4) summarizes technical efficiency scores under constant returns to scale (CRS) for the considered treatments. For fresh and dry weight, technical efficiency score for sorghum grown between *A. senegal* and *A. tortilis* rows (ST) is higher than other treatments, followed by sorghum grown between *A. tortilis* and *A. seyal* rows (TSY). However, grains weight or yield technical efficiency is higher for sorghum grown between pure *A. Senegal* rows (SS) followed by sorghum grown between *A. tortilis* and *A. seyal* rows (TSY). The overall technical efficiency is greater for sorghum grown between *A. tortilis* and *A. seyal* rows (TSY), followed by *A. senegal* and *A. tortilis* rows (ST). Control plants registered the lowest technical efficiency scores in all traits.

**Table 4** Technical efficiency scores for different planting combination

| Trees row combination | Technical Efficiency | | |
|---|---|---|---|
| | Fresh weight (Kg) | Dry weight (Kg) | Overall TE |
| NS | 0.913 | 0.916 | 0.90 |
| SS | 0.896 | 0.896 | 0.92 |
| ST | 0.976 | 0.976 | 0.95 |
| TT | 0.838 | 0.837 | 0.83 |
| TSY | 0.955 | 0.953 | 0.96 |
| SYN | 0.865 | 0.865 | 0.88 |
| NN | 0.934 | 0.935 | 0.94 |
| C | 0.813 | 0.817 | 0.82 |

## DISCUSSION

In this study *Acacia* trees combination may enhance soil available nitrogen, as compared to control soil. The improvement of soil fertility in terms of available nitrogen due to trees pruning and nitrogen fixation was well documented, by Worku *et al.*( 2014) and Nsabimana *et al.*(2008) who concluded that increase of soil fertility can be due to the litter fall addition from trees and shrubs to the surface soil. These results confirm the pervious findings of Tiedemann and Klemmedson (1993), *Acacia* litter contributes greatly to soil fertility due to the tree's ability to fix atmospheric nitrogen. In arid and semiarid areas, the soils under the *Acacia* canopy are usually improved and developed more than those outside the canopy, having higher nitrogen and water contents (Waldon, 1989). Also Kassa *et al.* (2017), mentioned the role of agrofrestry in soil fertility, agroforestry has the potential to maintain soil fertility, and stores higher soil organic carbon and nitrogen in proportion to the natural forest. As table 3, indicated, sorghum plants between trees were taller, have more leaves and produced significant amount of fresh and dry matter, comparing to control plants. The results obviously reveal the changing influence of the trees on sorghum crop performance under agroforestry; this changing can be explained by increasing nutrients between trees mainly N. This effect well documented. Nitrogen help to improve root system development, dry matter production, and other plant functions regulating crop yield and quality. This research findings was in consistence with Lawlor and Young (1989) and Shah *et al.* (2004), who stated N-fixing legumes in crop mixture systems can improve nitrogen uptake. Increasing of nitrogen content of leaves, due to a nitrogen fixation for leguminous plants (Fletcher *et al.*, 2013). Although all the species had increase sorghum growth, but the combination of *A. tortilis* and *A. seyal* with suitable practice such as pruning, mulching and increase distances between crop and trees appeared be the best management to enhance plant growth under arid condition. Recently, some researchers mention that suitable management to increase the productivity of understory crops in agroforestry is by pruning tree (Hou *et al.*, 2003), increasing distance between adjacent crop border row and tree line to minimize interspecific competition (Mao *et al.*, 2014; Wang *et al.*, 2016). The results revealed the influence of the *Acacia* trees on sorghum crop performance under agroforestry can be explain by increasing nutrients between trees. Noble *et al.* (2001) explained the relation between these nutrients and crop yield, as nutrients help to improve root system development, dry matter production, and other plant functions regulating crop yield and quality. The overall technical efficiency for sorghum grown between Acacia trees is better than technical efficiency of sorghum grown without agroforestry system (control plants), which means that sorghum production performance is greatly improved when planted in-between Acacia trees. The best technical efficiency is reported for sorghum grown between *A. tortilis* and *A. seyal* rows (TSY) followed by *A. senegal* and *A. tortilis* rows (ST). Although all the species had increase sorghum growth, but the combination of *A. tortilis* and *A. seyal* with suitable practice such as pruning, mulching and increase distances between crop and trees appeared to be the best management to enhance soil fertility and hence plant growth under arid condition.

## CONCLUSION

The results of this study concluded that all trees combination enhanced soil available nitrogen and sorghum plants growth, physiological traits, yields and technical efficiency of sorghum production. The combination consisting of A. *seyal*, *A. tortilis* and *A. senegal* as pure rows or in combination with each other has much higher effects on soil fertility and sorghum crop growth and yield. These findings were further confirmed by applying the technical efficiency analysis, where the best technical efficiency of resource use is reported for sorghum plants grown between rows of A. *tortilis* and A. *seyal* (TSY) followed by *A. senegal* and *A. tortilis* rows (ST). Tree species, especially legumes are essential for the improvement of soil fertility particularly nitrogen, in arid zone like Saudi Arabia, where the low soil fertility, shortage of rainfall and higher summer temperature, represented the major obstacle for crop production. The *Acacia* tree species improve soil fertility in different ways and they can be integrated into crop and forage production in this arid area, or in area with the same ecological condition.

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