Journal of Advanced Zoology

ISSN: 0253-7214
Volume 44 Special Issue-2 Year 2023 Page 4784:4792

Changes in Panicum maximum Jacq. *(Mombasa cv)* Canopy Cover and its Relation to Forage Productivity under *Leucaena Leucocephala* Alley Cropping and NPK Fertilization in an Arid Agroforestry Systems in Saudi Arabia

Diakalidia Kouyate[1*], Refaat A. Abohassan[2], Abdalla A. Elfeel[3]
[1,2,3] Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia
*Corresponding Author E-mail: dkouyate@stu.kau.edu.sa

Article History
Received: 08 Sept 2023
Revised: 29 Oct 2023
Accepted: 05 Nov 2023

Abstract

There is an increasing need for intercropping practices in drylands to increase land-use efficiency. Canopy cover is a great tool for assessing agricultural yield, as it is an indicator of plant health and productivity. The smartphone-based application Canopeo was used to measure the canopy cover (CC) of Panicum maximum Jacq. (Mombasa cv) under mixed intercropping with Leucaena and four (4) fertilization levels (control, 200 kg, 300 kg, and 400 kg of NPK). The forage yield and CC were measured for six (6) consecutive cuttings. Forage quality (N, P, K, and protein levels) was also analyzed.
The results revealed a highly positive correlation between the CC and crop yield and quality. In addition, the application of fertilizers produced higher CC, which was associated with higher yield and forage quality. The relatively low correlation between CC and yield in intercropping may be due to the high competition of the Leucaena tree. However, the entire intercropping system was positive (with an LER of 2.7), indicating better land-use efficiency.
The results indicate that intercropping in drylands would result in better land use. The application of NPK fertilizers increases crop CC, resulting in higher forage yield and quality.

Keywords: *Alley cropping; Agroforestry; Competition; Canopy Cover; Yield.*

1. INTRODUCTION

Alley cropping, also known as "inter-cropping," is the practice of planting rows of trees and/or shrubs to form alleyways where agricultural or horticultural crops are grown (USDA, 2021). This system improves soil nutrient accessibility in many ways, and the integration of woody species into farmlands enhances soil fertility and increases soil organic matter content via leaf litter and other materials from trees. Moreover, trees usually offer efficient nutrient cycling within a system (Grau et al., 2017). In addition, this system offers a more appropriate environment for increased activity of valuable microorganisms in the root zone (Lee & Jose, 2003). Recently, the effect of the trees in alley cropping gained growing interest due to the nutrient capture mechanism, in which trees' deep roots play the role of a "safety net" for capturing and leaching nutrients below the crops root zone (Pierret, et al., 2016), recycled to the topsoil Part of these through litterfall and fine roots decomposition (Liu, et al., 2019).
Various indicators, such as spectral vegetation indices and fractional green canopy cover (FGCC), have been developed to assess the extent of canopy growth (Meyer & Neto, 2008). FGCC is a non-destructive and relatively simple-to-measure variable used in ecology, environmental science, and agronomy to assess active green land cover at different spatial and temporal scales (Patrignani & Ochsner, 2015).
The two categories of software packages regarding FGCC are manual pixels and automatic color threshold classifications (Patrignani & Ochsner, 2015). Canopeo's pixel classification method, which employs red-to-green and blue-to-green color value ratios, has been demonstrated to differentiate green vegetation from non-green backgrounds (Wang & Naber, 2018).
The resulting image was black and white, with white pixels referring to the percentage of green cover and black to non-green. Smartphone-based apps. Several researchers have used the Canopeo application. For example, Lollato et al. (2016), Chung, et al. (2017), Graham et al. (2019), and Abreu et al.(2019) for diverse purposes.
Panicum maximum Jacq. (*Mombasa cv*) grass is a valuable forage of moderate to high quality, persistent, drought-resistant, and highly productive species (Murphy, 2010). It is used as a shelter crop and a soil improver

to improve fertility. In addition, Panicum maximum Jacq. (*Mombasa cv*) association with several legumes has improved yield for revegetation purposes. *The L. leucocephala* family of Fabaceae, a fast-growing and evergreen tree, is one of the highest qualities and most palatable fodder trees in the tropics (Ecoport, 2009) with nitrogen fixation potential (150 to 300 kg/ha).

This study focuses on the assessment of the effect of *L. leucocephala* alley cropping on Panicum maximum Jacq. (*Mombasa cv*) canopy cover and its relationship to yield using the Canopeo App.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted at an agroforestry system site located at the Agricultural Research Station of King Abdulaziz University, Hada Al-Sham, approximately 80 km northeast of Jeddah (21° 48 3″ N, 39° 43' 25″ E, elevation 240 m.a.s.l.). The site receives minimal annual rainfall (less than 100 mm/annum) with poor sandy loam and pH ranging from 7.1 to 7.99 (Al-Solimani et al., 2003). The experiment was conducted in the field using a drip irrigation system. The agroforestry system was established, with 10 m between rows, and 4.5m within row distances, and a row length of 17.5 m.

2.2 Experimental design

The experiment was a replicated split-plot design in a randomized complete block design. The main plot was represented by *Leucaena* × *Panicum maximum Jacq*. intercropping, whereas the subplots were occupied with fertilization treatments (0, 200, 300, and 400 kg/ha). The experiment was monitored for the entire year to account for seasonal variations.

2.3 The Canopeo App.

The Canopeo app. used in this study is an automated color threshold picture analysis tool using red–green–blue (RGB) color values developed by Oklahoma State University for CC measurement (Shepherd et al., 2018). It grants access to the operator to make managerial choices in the field. The FGCC ranges from 0-1 (no green to 100% green CC) (**Figure 1**).

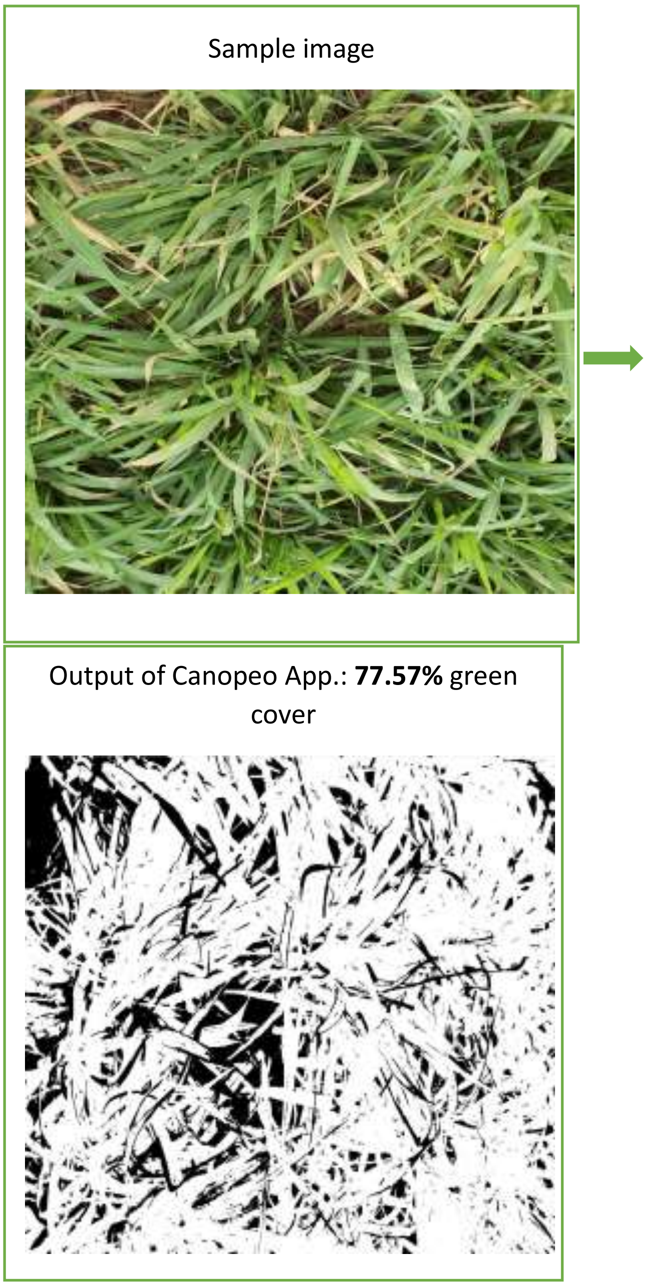

Figure 1: A sample of GCC percentage measurement recorded on 28/08/2021 at 9h28 AM

2.4 Measurements

Six (6) cuttings were collected during the experiment (February 2020 to April 2021). In each cutting harvest, a one-meter square (1 m^2) quadrat was thrown randomly over the growing plants in each plot/treatment in a total of 24 plots. Within each plot, plant height was measured for three sampled plants; then, the shoots inside the quadrat were trimmed and fresh weighed, and samples were oven-dried to estimate the dry weight and forage yield per hectare. Forage yield was estimated by converting 1 m^2 of fresh forage weight/quadrat into tons/ha. In each plot, downward-facing images were captured from random spots using the Canopeo App. on the Android smartphone. The camera was kept at approximately 60 cm from the top of the canopy to maintain an appropriate distance between it and the plant top, which is essential to minimize the overestimation of FGCC because canopy leaves are too close to the lens of the camera (Hoyos□Villegas et al., 2014).

Leaf samples were collected to determine the N, P, K, and protein levels. Nitrogen was analyzed using an automated micro-Kjeldahl method and multiplied by 6.25 to estimate the protein content (Miller & Horneck, 1998). Phosphorus was determined by the UV-visible spectrophotometric method (Pradhan & Pokhrel, 2013). While potassium was determined using atomic absorption spectrophotometry (Adelantado et al., 1991).

2.5 Statistical analysis

Analysis of variance was conducted using SAS (Statistical Analysis System, SAS System), and the means were obtained and tested by Duncan's Multiple Range Test.

3. RESULTS AND DISCUSSION

3.1 Crop canopy cover

In this study, measurements of FGCC with the Canopeo App. during six consecutive measurements (cuttings) resulted in significantly different canopy cover (CC) percentages between plant growth under intercropping and monocropping systems in five out of the six measurements (**Table 1**). The highest CC of 72.58 % was obtained in intercropping systems during harvest 6 meanwhile, monocropping systems also recorded the highest CC of 68.51% in the same harvest. Similar to the cropping system, the data showed that the addition of NPK fertilizers produced a significantly higher CC percentage in plots treated with fertilizer than in the untreated control plots (**Table 2**). Higher doses of fertilization (400 kg/ha) resulted in higher CC in all six measurements (harvests), followed by 300 and 200 kg/ha, and the lowest was reported in the control untreated plots. Similar results were reported by González Marcillo et al. (2021), who reported higher agronomical measurements of *Panicum*, such as plant height and coverage, in different treatments, but with the lowest in the control. The highest LAI with CC measurement was observed in the intercropping system compared to the same assessed heights in the monocropping system. This result is in contrast with the study of Rodrigues et al. (2016) who studied Mombasa grass characterisation at different heights of grazing in an intercropping system with Babassu and monoculture, CC under monoculture was high compared to the intercropping system. Therefore, shade was considered the main factor reducing LAI in the intercropping system. The young age of the current study agroforestry system and the low tree canopy cover with the addition of NPK fertilizer led to the highest LAI in the intercropping system.

Table 1 Mean differences in *Panicum maximum Jacq.* Plant Length (cm), Fresh Weight (Tons/ha), Yield (Tons/ha) and Canopy Cover (%) between intercropping (I) and Mono-cropping (M) under the effects of *Leucaena Leucocephala* alley cropping system across 6 cutting harvests.

Harvest	Cropping	Variables			
		Plant Length	**Fresh Weight**	**Yield**	**Canopy Cover**
Harvest 1	I	0.96^{b}	2.79^{b}	9.92^{b}	68.95^{a}
	M	1.31^{a}	5.85^{a}	14.03^{a}	55.76^{b}
Harvest 2	I	1.14^{b}	3.25^{b}	10.11^{b}	68.79^{a}
	M	1.41^{a}	4.41^{a}	12.54^{a}	62.84^{b}
Harvest 3	I	1.69^{b}	2.00^{b}	5.17^{b}	68.85^{a}
	M	1.86^{a}	2.73^{a}	7.80^{a}	65.45^{a}
Harvest 4	I	1.28^{b}	1.23^{b}	4.00^{a}	68.51^{a}
	M	1.40^{a}	2.18^{a}	5.52^{a}	65.33^{b}
Harvest 5	I	0.85^{a}	1.41^{a}	4.86^{a}	64.48^{b}
	M	0.85^{a}	1.81^{a}	4.39^{a}	68.43^{a}
Harvest 6	I	1.23^{b}	3.77^{b}	13.05^{a}	72.58^{a}
	M	1.35^{a}	5.89^{a}	13.77^{a}	68.51^{b}

Using Duncan's Multiple Range Test, the means within each column by harvest, crop, and cropping with the same letter are not significantly different at p=0.05

Table 2: Mean values of *Panicum maximum Jacq.* Plant Length (cm), Fresh Weight (Tons/ha), Yield (Tons/ha) and Canopy Cover (%) under the effects of four NPK fertilization (T0= 0 kg, T1= 200 kg, T2=300 kg and T3= 400 kg) across 6 cutting harvests

Harvests	**Fertilization Level**	**Variables**			
		Plant Length	**Fresh Weight**	**Yield**	**Canopy Cover**
Harvest 1	T 0	1.03^{c}	3.43^{b}	9.27^{c}	52.81^{b}
	T 1	1.12^{bc}	3.88^{ab}	10.42^{bc}	58.92^{b}
	T 2	1.16^{ab}	4.53^{ab}	12.31^{b}	67.07^{a}
	T 3	1.24^{a}	5.17^{a}	15.92^{a}	70.63^{a}
Harvest 2	T 0	1.12^{c}	3.31^{a}	8.12^{c}	57.65^{b}
	T 1	1.26^{b}	3.81^{a}	10.79^{b}	61.84^{b}
	T 2	1.34^{ab}	4.06^{a}	12.17^{b}	68.84^{a}
	T 3	1.40^{a}	4.16^{a}	14.23^{a}	74.93^{a}
Harvest 3	T 0	1.63^{c}	1.93^{b}	4.98^{c}	61.00^{c}
	T 1	1.71^{bc}	2.14^{b}	6.07^{bc}	64.00^{ab}
	T 2	1.81^{b}	2.40^{b}	6.74^{b}	68.97^{ab}
	T 3	1.95^{a}	2.98^{a}	8.15^{a}	73.65^{a}
Harvest 4	T 0	1.19^{c}	1.25^{c}	3.32^{b}	62.77^{b}
	T 1	1.33^{b}	1.52^{b}	3.96^{ab}	64.06^{b}
	T 2	1.40^{ab}	2.00^{a}	4.75^{ab}	69.57^{a}
	T 3	1.46^{a}	2.06^{a}	7.03^{a}	71.28^{a}
Harvest 5	T 0	0.78^{c}	1.09^{b}	2.99^{b}	62.41^{c}
	T 1	0.84^{bc}	1.36^{ab}	3.59^{b}	66.10^{b}
	T 2	0.88^{ab}	1.70^{ab}	4.88^{b}	68.13^{ab}
	T 3	0.91^{a}	2.30^{a}	7.03^{a}	68.87^{a}
Harvest 6	T 0	1.06^{c}	4.14^{a}	11.33^{d}	67.11^{c}
	T 1	1.28^{b}	5.01^{a}	12.71^{c}	70.51^{b}
	T 2	1.36^{ab}	4.79^{a}	13.98^{b}	71.33^{b}
	T 3	1.46^{a}	5.39^{a}	15.61^{a}	73.24^{a}

Using Duncan's Multiple Range Test, the means within each column by harvest, crop, and fertilization with the same letter are not significantly different at p=0.05

3.2 Forage yield

In this study, the effects of intercropping and NPK fertilization on forage yield were assessed, in addition to the correlation between CC and forage yield. Analysis of variance showed that under the intercropping system, the forage yield parameters measured were significantly affected, including plant height (m), fresh weight, and forage yield (tons/ha) ($p<0.05$). The monocropping plots produced significantly higher yield values than the intercropping system in all harvests, except for harvest 5 (**Table 1**). The same was reported by Sousa et al. (2007), who discovered that shade has a significant impact on forage dry matter content owing to a larger proportion of leaves and a higher ratio of living: dead material on grass. This result may be attributed to the fast prolific growth of the Leucaena tree, which leads to greater competition. According to Gobbi et al. (2011), another factor that affects grass yield in the intercropping system is leaf architecture modification, because the increased specific leaf area leads to a decrease in forage mass density and reduces sclerenchymatous tissue and palisade parenchyma thickness. However, for the whole system, the net gain of Panicum maximum Jacq., intercropped with Leucaena trees in the dry site of Hada Ash-Sham, produced a positive effect with an LER value of 2.7 (**Table 4**), indicating better land-use efficiency under intercropping.

Similarly, the intercropping system significantly ($p<0.05$) affected the yield production in tons ha-1 over the six harvests (**Table 1**). The highest total yield production per year (83.8 tons ha-1y-1) was reported in the combination of NPK 100 kg/ha under monocrop plots, whereas a lower yield was reported in the 400 kg/ha and control untreated plots under intercropping (**Figure 2**). In general, the combined effects of NPK and monocrop planting produced higher yields than those of intercropping and NPK. The reduction in forage yield under alley cropping was approximately 20–25%; however, considering the whole system, the effect was positive. This was related to the significant effect of intercropping on tree growth. This may call for future investigation of the addition of Leucaena forage as a supplement to Panicum maximum Jacq. at certain percentages to increase the forage output of the intercropping system. It is well known that the production of Leucaena forage is very high owing to its toxic effects .Mimosine in high quantities, it is highly needed to investigate the best Panicum maximum Jacq.: Leucaena ratio that will not affect the forage quality.

The data presented in **Table 3** reveal a very high positive correlation between CC and crop dry matter production and yield (especially in monocrops). Despite the higher CC in intercropped plots compared to the monocrop, the correlation of CC with yield was lower under intercropping. This confirms the competitive effects of the Leucaena tree, which occurs between the crop and tree roots for nutrients, resulting in heavy competition and reduced crop yield (Jose et al., 2000). The positive correlation between CC and forage yield and quality highlights the importance of CC measurement as an indicator of crop yield and quality.

Regarding the application of NPK fertilizer, there was no significant ($p<0.05$) effect on crop yield and quality (**Figure 3**). Nevertheless, there was a strong relationship between CC and yield under the different NPK fertilizer treatments (**Table 2**). The NPK level of 400 kg/ha (T3) resulted in a higher canopy cover percentage and yield (ton ha-1) than the control, followed by T2 (300 kg/ha) and T1 (200 kg/ha). This result is similar to that of Galindo et al. (2017), who found that N fertilizer had a positive influence on Panicum maximum cv. mombasa dry matter yield (DMY), an increase in DMY was observed with increasing N doses. The positive correlation of NPK doses with CC may be attributed to N, which would lead to great growth and green matter production, and consequently, to high crop forage yield and quality. NPK fertilization substantially enhances productivity and increases numerous parameters that contribute to yield and quality (Bakhashwain & Elfeel, 2012; Li et al., 2010).

	Intercropping		**Monocropping**	
Harvests	**Canopy Cover Correlation with Variables**			
	Fresh weight	Yield	Fresh weight	Yield
Harvest 1	0.20 **(p<0.54)**	0.45 **(p<0.14)**	0.36 **(p<0.25)**	0.61 **(p<0.04)**
Harvest 2	0.59 **(p<0.43)**	0.82 **(p<0.001)**	0.49 **(p<0.11)**	0.81 **(p<0.001)**
Harvest 3	-0.03 **(p<0.92)**	0.04 **(p<0.89)**	0.62 **(p<0.03)**	0.55 **(p<0.06)**
Harvest 4	0.66 **(p<0.02)**	0.73 **(p<0.007)**	0.58 **(p<0.05)**	0.67 **(p<0.02)**
Harvest 5	0.18 **(p<0.57)**	0.49 **(p<0.11)**	0.15 **(p<0.65)**	0.01 **(p<0.97)**

Table 3: Pearson Correlation Coefficient of *Panicum maximum Jacq.* canopy cover with fresh weight and yield in intercropping and monocropping plots across 6 cutting harvests

Harvest 6	0.48 **(p<0.11)**	0.68 **(p<0.01)**	-0.15 **(p<0.65)**	0.77 **(p<0.003)**

Table 4: Land Equivalent Ratio of the Total Yield for the 6 cutting harvests

	Intercrop Yield (t/ha)	**Monocrop Yield (t/ha)**	**Partial LER**
Panicum	47.11	58.05	47.11/58.05=0.81
Tree	22.59	11.87	22.59/11.87=1.90
Total	-	-	**2.71**

LER>1 indicates that intercropping is a yield advantage for monocropping.

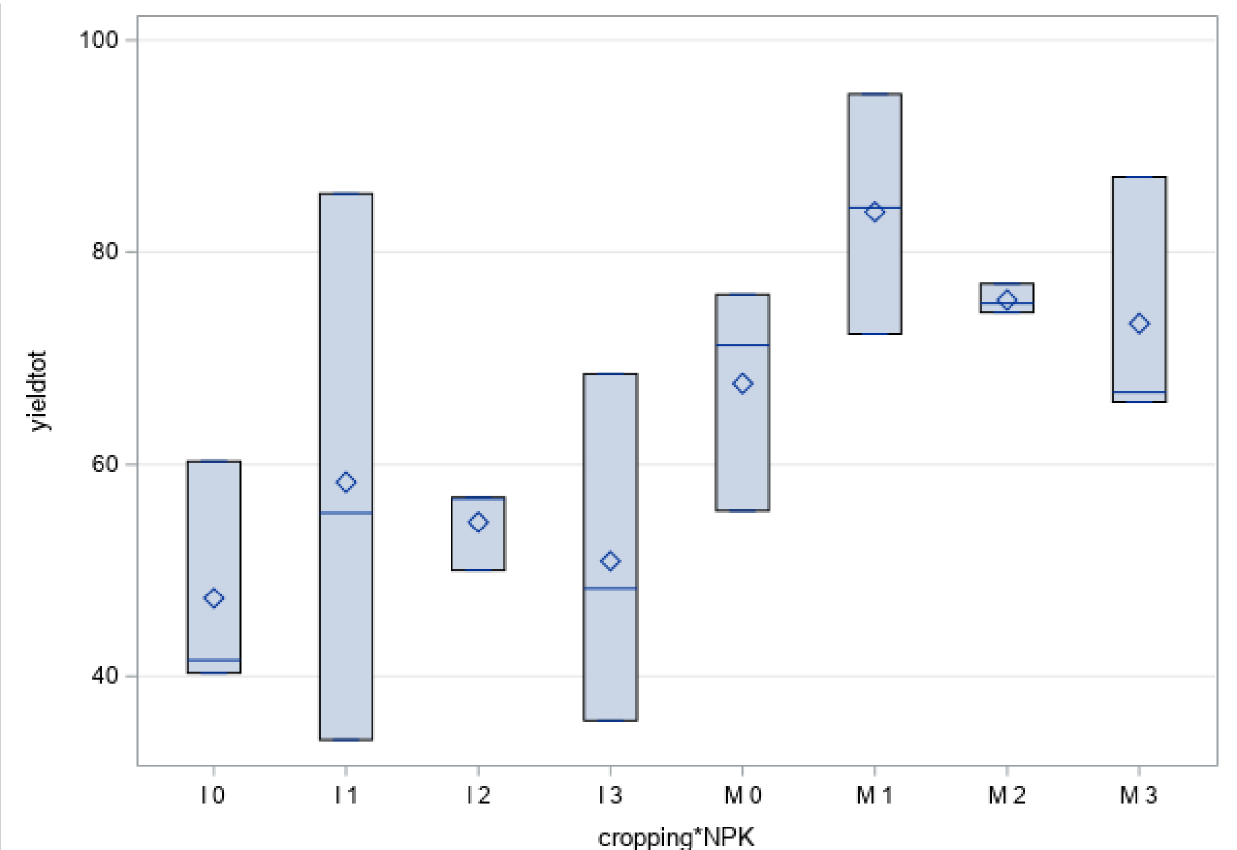

Figure 2: Mean value (Mean ± SD) Distribution of Total Yield (Tons $ha^{-1}y^{-1}$) of *Panicum maximum Jacq.* grown between the alleys of *Leucaena leucocephala* and different NPK concentrations under an arid land agroforestry system.

3.3 Forage quality

The data presented in **Figure 3** revealed that the effects of intercropping and fertilization on forage quality (protein and N, P, and K content) were high. The protein content in *Panicum maximum Jacq.* leaves ranged from 10.8 to 12.2%, nitrogen (N) ranged from 1.7 to 2.0%, and phosphorus (P) varied from 0.28 to 0.32% in intercropping and monocropping, respectively. No difference was observed between monocropping and intercropping for potassium (K) with 0.03% monocropping and intercropping. Similar to forage yield, the combined effects of monocropping and NPK fertilization resulted in higher forage quality values than the intercropping and NPK fertilization combination.

The two-way mean distribution value of total yield (Tons/ha/year) with different NPK concentrations displayed in **Figure 2** indicates that the different NPK doses positively impacted the yield throughout the experiment. This graph confirms the result obtained in **Table 2**, which indicates a positive difference in yield obtained under the levels of fertilization compared to the control plot. The higher the dose of NPK, the higher was the yield obtained for the control (0NPK). In previous studies, Galindo et al. (2017) and Galindo et al. (2019); Yamika et al. (2021); similar results were obtained by correlating high fertilizer doses with high yield. Meanwhile, the yield obtained in monocropping was higher than that under intercropping at all levels of fertilization.

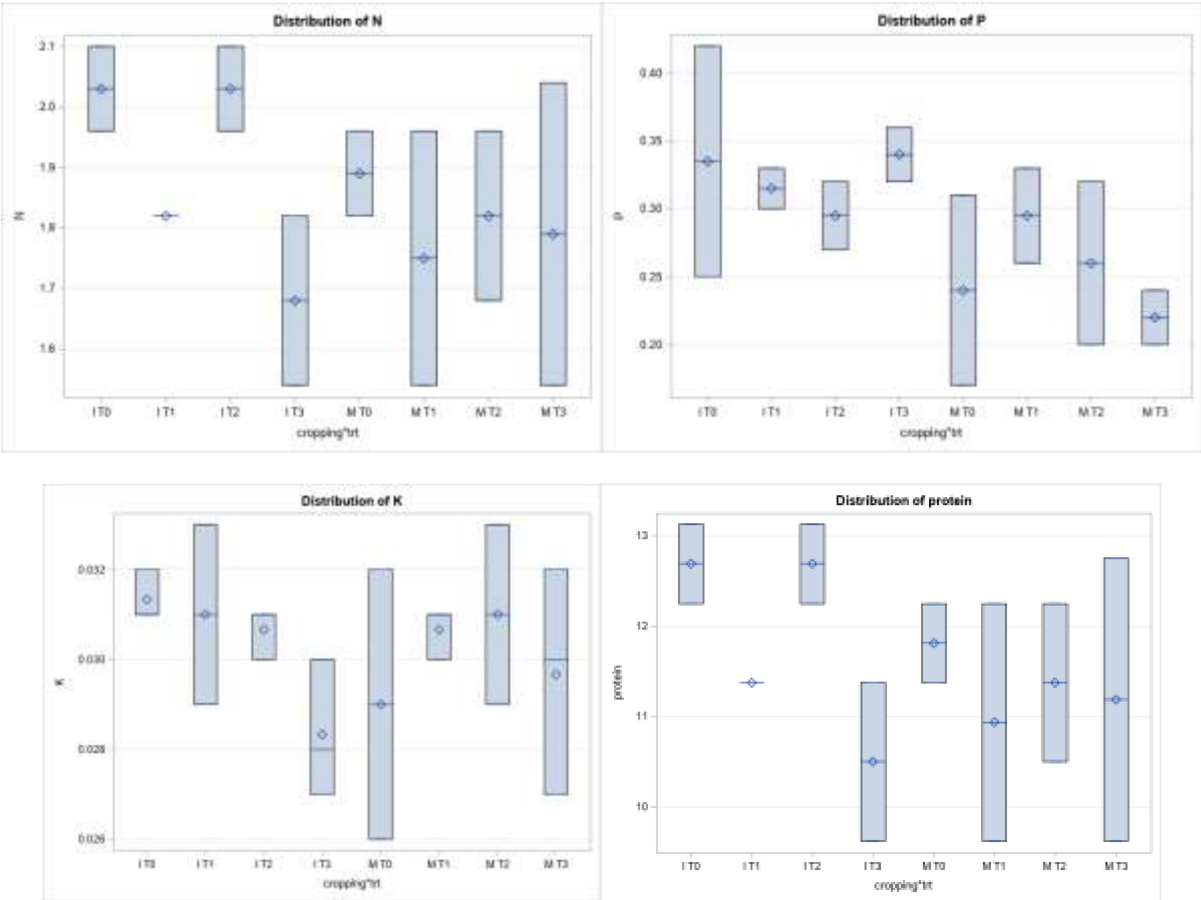

Figure 3: Mean value (Mean ± SD) Distribution of forage quality percentages (N, P, K and Protein) of *Panicum maximum Jacq.* grown between the alleys of *Leucaena leucocephala* and different NPK (treatments) concentrations under an arid land agroforestry system.

4. CONCLUSION

Leucaena Leucocephala intercropped with *Panicum maximum Jacq.* increased crop canopy cover, reflecting better forage yield and quality. Although the yield, in general, was higher in monocrops than in the sole crop, the whole intercropping system was positive. This result may be attributed to the light shaded by *Leucaena L.,* which reduces competition for light between understory crops (*Panicum maximum Jacq.*) and *Leucaena L.* trees. In addition, the young stage growth of *Leucaena L.* trees may also explain its positive effect on understory crops.

Conflict of interest

The authors declare that they have no conflict of interest.

References:

Adelantado, J., Martinez, V., Garcia, A. & Reig, F., 1991. Atomic-absorption spectrometric determination of calcium, magnesium and potassium in leaf samples after decomposition with molten sodium hydroxide. *Talanta,* 38(9), pp. 959-963.

Al-Solimani, S. G., El-Toukhy, A. & Al-Zahrani, S., 2003. Mineral characteristics, classification and evaluation of the soils of Hada Al-Sham research station, Kingdom of Saudi Arabia. *J. Environ. Sci., Ain Shams University,* Volume 6, pp. 285- 322.

Bakhashwain, A. & Elfeel, A., 2012. Foliage productivity and quality of valuable medicinal plant (Clitoria ternatea L.) as affected by different fertilizers. *Journal of Medicinal Plants Research ,* 6(25), pp. 4225-4230.

Galindo, F. et al., 2017. Application of different nitrogen doses to increase nitrogen efficiency in mombasa guinegrass ('Panicum maximum'cv. mombasa) at dry and rainy seasons. *Australian Journal of Crop Science,* 11(12), pp. 1657-1664.

Galindo, F., Buzetti, S., Teixeira Filho, M. & Dupas, E., 2019. Rates and sources of nitrogen fertilizer application on yield and quality of Panicum maximum cv. Mombasa. *Idesia,* 37(2), pp. 67-73.

Gobbi, K. et al., 2011. Specific leaf area and quantitative leaf anatomy of signalgrass and forage peanut submitted to shading. *Revista Brasileira Zootecnia, Viçosa,* 40(7), pp. 1436-1444.

González Marcillo, R. et al., 2021. Assessment of Guinea grass Panicum maximum under silvopastoral systems in combination with two management systems in Orellana Province, Ecuador. *Agriculture,* 11(2), p. 117.

Grau, O. et al., 2017. Nutrient-cycling mechanisms other than the direct absorption from soil may control forest structure and dynamics in poor Amazonian soils. *Scientific Reports,* 7(1), pp. 1-11.

Hoyos□Villegas, V., Houx, J., Singh, S. & Fritschi, F., 2014. Ground□based digital imaging as a tool to assess soybean growth and yield. *Crop Science,* 54(4), pp. 1756-1768.

Jose, S. et al., 2000. Defining competition vectors in a temperate alley cropping system in the midwestern USA: 3. Competition for nitrogen and litter decomposition dynamics. *Agroforestry systems,* 48(1), pp. 61-77.

Lee, K. & Jose, S., 2003. Soil respiration and microbial biomass in a pecan-cotton alley cropping system in Southern USA. *Agroforestry systems,* 58(1), pp. 45-54.

Liu, L. et al., 2019. Fine-root turnover, litterfall, and soil microbial community of three mixed coniferous–deciduous forests dominated by Korean pine (Pinus koraiensis) along a latitudinal gradient. *Frontiers in Plant Science,* Volume 10, p. 1298.

Li, W., Lu, J., Fang, C. & Li, X., 2010. Effect of NPK application on yield, nutrients and water utilization under sudangrass and ryegrass rotation regime. *Agricultural Sciences in China,* 9(7), pp. 1026-1034.

Meyer, G. E. & Neto, J. C., 2008. Verification of color vegetation indices for automated crop imaging applications. *Computers and electronics in agriculture,* 63(2), pp. 282-293.

Miller, R. & Horneck, D., 1998. Determination of total nitrogen in plant tissue. In: Y. Kalra, ed. *Handbook of Reference Methods for Plant Analysis.* New York, USA: Taylor and Francis Group, p. 285.

Mukherjee, P., Kumar, V., Kumar, N. & Heinrich, M., 2008. The Ayurvedic medicine Clitoria ternatea-From traditional use to scientific assessment. *Journal of Ethnopharmacology,* 120(1), pp. 291-301.

Murphy, S., 2010. Tropical perennial grasses – root depths, growth and water use efficiency. *NSW Industry and Investment, Primefacts,* Volume 1027.

Patrignani, A. & Ochsner, T., 2015. Canopeo: A powerful new tool for measuring fractional green canopy cover. *Agronomy Journal,* 107(6), pp. 2312-2320.

Pierret, A. et al., 2016. Understanding deep roots and their functions in ecosystems: an advocacy for more unconventional research. *Annals of botany,* 118(4), pp. 621-635.

Pradhan, S. & Pokhrel, M., 2013. Spectrophotometric determination of phosphate in sugarcane juice, fertilizer, detergent and water samples by molybdenum blue method. *Scientific world,* 11(11), pp. 58-62.

Rodrigues, M. et al., 2016. Mombasa grass characterisation at different heights of grazing in an intercropping system with Babassu and monoculture. *Semina: Ciências Agrárias,* 37(4), pp. 2085-2098.

Shepherd, M., Lindsey, L. & Lindsey, A., 2018. Soybean canopy cover measured with Canopeo compared with light interception. *Agricultural & environmental letters,* 1(180031), p. 3.

Sousa, L. et al., 2007. Productivity and nutritional value of Brachiaria brizantha cv. Marandu in a silvopastoral system. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia,* 59(4), pp. 1029-1037.

USDA, 2021. *U.S. Department of Agriculture.* [Online] Available at: https://www.fs.usda.gov/nac/practices/alley-cropping.php [Accessed 28 08 2021].

Wang, Y. & Naber, M., 2018. *Use the Canopeo app to determine potato canopy cover,* Madison: University of Wisconsin Extension.