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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng EFFECT OF RABBIT MANURE AND ROW ARRANGEMENT ON CROP YIELD

UNDER FINGER MILLET AND GROUNDNUT INTERCROPPING SYSTEMS IN A SEMI-ARID NIGERIA

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ABSTRACT

Field trials were conducted at the Research and Training farm of the Centre for Dryland Agriculture, Bayero University Kano (Latitude 11° 58' N and Longitude 8°26' E and 475 m above sea level) and at community-based demonstration farm, Dawakin Kudu (Latitude 11°84 N and Longitude 8° 59" E) Kano State, Nigeria during the 2019 rainy season, to investigate the effects of rabbit manure (RM) and row arrangement (RA) on finger millet and groundnut intercropping system. The treatments consisted of six row arrangements (1:1, 1:2, 2:1, 2:2, 2:4, and alternate stand) and four levels of rabbit manure $(0, 1.5, 2.5, and 3.5 t ha^{-1})$ and one level of NPK fertilizer. The treatments were laid out in a split-plot design, with row arrangement (RA) occupying the main plot and rabbit manure (RM) occupying the sub plot, which were replicated three times. Findings revealed that Rabbit manure application significantly (P < 0.05) affected most finger millet and groundnut yield parameters, except for row arrangement which had minimal impact. The optimal rate of rabbit manure application depended on the specific parameter, location, and crop. For finger millet, application of RM increased spike weight, panicle weight, 1000-grain weight, and total grain yield at Dawakin Kudu but only affected spike weight at BUK. For groundnut, RM application increased the number of pods per plant, mean pod weight, and 100-kernel weight at Dawakin Kudu, while only affecting the number of pods per plant at BUK. Intercropping was generally more productive than sole cropping, with the most productive combinations varying by location. Therefore, it could be recommended for farmers in the Sudan savanna to consider the possible adoption of the application of rabbit manure at a rate of 2.5–3.5 t ha⁻¹ to increase finger millet and groundnut vields.

Keywords: Arrangement, Crop, Effect, Manure and Yield

INTRODUCTION

Intercropping is a crop management strategy in which two or more economically significant species grow alongside one another for at least a portion of their individual production cycles (Aseng *et al.*, 2014). It is essential to the production of food for subsistence in both developed and developing nations (Maitra *et al.*, 2021; Gitari *et al.*, 2019). Compared to solitary crops, it typically produces larger yields with more yield stability and effective nutrient use (Li *et al.*, 2023). Cereal legumes, in particular millet-groundnut, maize-soybean, maize-cowpea, maize-groundnuts, and rice-pulses, are the main component of intercropping systems (Chamkhi *et al.*, 2022). In actuality, intercropping is the cropping system's value addition, which can guarantee increased output, resource efficiency, and revenue (Manasa *et al.*, 2018).

Farmers in the sub-Saharan Africa are increasingly using cereals and legumes together, most likely because legumes can fix atmospheric nitrogen for the benefit of the cereals (Kermah *et al.*, 2018), preventing erosion, increasing soil fertility and reduce the risk of monocropping (Daryanto *et al.*, 2020). Planting pattern adaptability and crop compatibility selection are key components in the establishment of a workable and profitable intercropping system (Brooker *et al.*, 2014).

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Finger millet ranks fifth among the top 10 intercropped cereals (Thilakarathna and Raizada, 2015). It's commonly paired with legumes like pigeon pea, groundnut and soybean (Thilakarathna *et al.*, 2015). Finger millet thrives under minimal input conditions, tolerating drought, pests, and diseases (Awol *et al.*, 2013). This makes it a preferred crop for many African farmers. Furthermore, finger millet addresses a crucial dietary gap. It provides essential amino acids like methionine, often missing in diets based on starchy staples like maize, yam, and cassava (Chetan and Mellashi, 2007). Finger millet is a nutritious grain containing a good amount of protein (7.6g per 100g), carbohydrates (88g per 100g), and fiber (3g per 100g). It's also a source of essential minerals like calcium (37mg per 100g) and vitamins like Vitamin A, B1, B2, and niacin. Consuming finger millet regularly has been linked to benefits such as a reduced risk of gastrointestinal infections and improved blood sugar control, potentially aiding diabetic individuals. (Jayawardana *et al.*, 2022).

Packed with nutrients, groundnuts are not only a valuable food source but also an industrial powerhouse. They contain a substantial amount of oil, protein, carbohydrates, minerals, and vitamins. In addition to food, groundnuts are used in a variety of industrial products, including paints, lubricants, and insecticides (Variath and Janila, 2017). Groundnuts improve soil health in crop rotations thanks to their nitrogen-fixing abilities (Jaiswal *et al.*, 2017). Unfortunately, groundnut yields in sub-Saharan Africa (SSA) are much lower than their potential, averaging only 964 kg/ha compared to potential yields of 3500 kg/ha reported in other regions (African Institute of Corporate Citizenship, 2016). Several factors are responsible for the low groundnut yields in SSA. These include environmental challenges like drought and poor soil fertility, as well as attacks from pests (aphids, thrips, termites) and diseases (groundnut rosette, leaf spot, rust). Additionally, farmers in the region often use outdated varieties, lack access to good agronomic practices, and have limited support from agricultural extension services (Coulibaly *et al.*, 2017).

Poor soil quality, caused by declining nutrients and degradation, is a significant obstacle to growing crops across much of Sub-Saharan Africa, including Nigeria's Savanna region (Shehu *et al.*, 2015). Luckily, using fertilizer can improve this situation. Inorganic fertilizers, despite their benefits for crop growth, can be a double-edged sword. They risk polluting soil, air, and water sources, potentially impacting human health and jeopardizing the sustainability of farming (Adhikary *et al.*, 2012). Fortunately, using organic manure offers a way to reduce these environmental drawbacks.

In Nigeria's Sudan Savanna region, traditional farming practices often involve haphazardly mixing crops together without any plan for optimizing sunlight exposure (Jemo *et al.*, 2023). This lack of strategic crop arrangement is further supported by Haruna *et al.* (2011) who found that while farmers in the region do intercrop, they don't consider row placement, leading to generally lower yields. The case of millet and groundnut intercropping exemplifies this issue. The absence of proper row arrangement creates intense competition between and within the crops themselves (inter and intraspecific competition) and makes them less effective against weeds, ultimately resulting While Nigeria's Sudan Savanna Zone has extensive land ideal for grain production (millet, maize, sorghum, rice, and wheat) (FFD, 2012), crop yields there are far lower than the global average. The zone's average yield sits at just 1.7 tons per hectare compared to the world's average of 4.0 tha-2 (FAOSTAT, 2012). Given the low yields of grain crops in Nigeria's Sudan Savanna Zone, this study aimed to assess how finger millet and groundnut intercropping systems perform under different conditions. The research compared the effects of varying levels of rabbit manure application and different row arrangements to identify the most productive combination for this region.

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MATERIALS AND METHODS

Site Description

Field trials were conducted during the 2019 rainy season at the research and training farm of the Centre for Dryland Agriculture, Bayero University Kano, Nigeria (Latitude 11⁰58'N and Longitude 8⁰26' E and 475 m above sea level) and at community-based demonstration farm at Dawakin Kudu local government area (Latitude 11⁰84 N and Longitude 8⁰59 E) Kano State, Nigeria. The two sites are characterized by a sandy loamy soil textural class, receives annual rainfall of 400 - 650 mm.

Treatments and Experimental Design

The treatments consisted of six row arrangements (1:1, 1:2, 2:1, 2:2, 2:4, and alternate stand) and four levels of rabbit manure $(0, 1.5, 2.5, and 3.5 t ha^{-1})$ and one level of NPK fertilizer. The treatments were laid out in a split-plot design, with row arrangement (RA) occupying the main plot and rabbit manure (RM) in the sub plot, which were replicated three times.

Cultural Practices

The variety of finger millet used was chabrown (Ex-Jos). The seed color is deep red, it is the most common variety available in Nigeria, and it matures between 90 and 120 days. It gives a yield of 580–785 kg ha⁻¹, while the groundnut variety used was SAMNUT 23; early maturing (80–100 days), good kernel yield (2.0–2.5 t ha⁻¹), good fodder yield (2.0 t ha⁻¹), and high oil content (56%). The land was cleared, harrowed and made into ridges as soon as the rains were established. Partially decomposed rabbit manure was manually applied at a depth of approximately 15 cm after grooves were created. To enable sufficient decomposition, it was also hoe-covered for seven days prior to seeding, following each treatment protocol.

The treatment constituted the basis for manually sowing the finger millet. Five seeds were planted in each hole using the dibbling sowing technique, which was later thinned to two plants per stand at four WAS. The spacing was set at 75 cm between rows and 10 cm within rows at a depth of around 1 cm. The groundnut was thinned to 2 plants per stand at 2 WAS after being seeded with 3 seeds per hole at 75 cm inter-row and 30 cm intra-row spacing. Fertilizer was applied to the finger millet at a rate of 60 kg N, 30 kg P₂O₅ and 30 kg K₂O per hectare. Compound fertilizer (NPK 15-15-15) was used to supply the P, K, and half of the N requirement at 2 WAS. The second half of N was applied as top dressing at 6 WAS using urea (46% N). For groundnut, fertilizer was applied at a rate of 20 kg N, 54 kg P₂O₅ and 20 kg K₂O. Basal application of 20-20-20 kg NPK (15:15:15) and 34 kg SSP (18%) was added to balance the phosphorus. For both crops, weeds were manually controlled using hoe weeding at WAS 3 and 6. But the prevalence of insect pests was reduced by hand-picking them as soon as they were discovered and destroying them afterwards. Finger millet was harvested at maturity when the panicles turned brownish in color, as indicated by the free threshing of the grains when the heads of fingers were squeezed with the hand. It was cut at about 5cm above ground level using a sickle and allowed to dry before threshing. The groundnut was harvested when the leaves turned yellowish in color or by examining the pods inside the shell when they became brownish in color by digging out some of the pods with the aid of hoes.

Data Collection

Groundnut yield and yield components

The mean pod weight, pod yield, and kernel yield were determined at harvest. At harvest, 20 pods were sampled from each plot and air dried, and weight was taken using a weighing scale and recorded as the mean pod weight (kg). Similarly, pod yield and kernel yield (kg ha⁻¹) were obtained from the five tagged plants from each net plot area using a digital weighing scale. The values obtained were extrapolated to hectare basis, respectively.

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Finger millet yield and yield components

Spike weight plant⁻¹ (g), panicle weight and grain yield (kg ha⁻¹) were measured separately for each plot using an electronic scale. The spike harvested from five (5) plants from each plot was weighted, and the average obtained was recorded as spike weight per plant. Similarly, the panicle weight plot was weighed and recorded. Grain yield per plot was equally weighed after threshing and winnowing using a sensitive weighing scale. The values obtained for panicle weight per plot and grain yield per plot were, however, extrapolated to a per hectare basis (Kg ha⁻¹).

Land Equivalent Ratio (LER)

LER was calculated to determine the intercrop advantage. Relative yield was determined by dividing intercrop yield of each crop by yield of sole crop. It measures the effectiveness of intercropping in utilization of resources compared to sole cropping (Dhima *et al.*, 2007; Takim, 2012). From the sum of relative yields, the land equivalent ratio (LER) was calculated mathematically;

$$LER = LA + LB = \frac{Ya}{sb} + \frac{Yb}{sa} \qquad \dots (1)$$

Where LA and LB are the LER for individual crops, Ya and Yb are the individual crops yield in intercropping, and Sa and Sb are their yield as sole crops. A LER greater than 1.0 shows that intercropping is more efficient than sole cropping and a LER less than 1.0 shows that intercropping is disadvantageous. Willey (1985) indicated that a LER of 1.25 can be interpreted as 25% greater yield for intercropping or as 25% greater area requirement for the monocrop system.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using JMP 2017. Significantly different treatment means were compared using student Newman-Keuls test (SNK) at 5% level of probability. The Land Equivalent Ratio (LER) was used to determine the intercrop advantage.

RESULTS AND DISCUSSION

Effect of Rabbit Manure and Row Arrangement on spike weight, panicle weight, straw yield, 1000 seed weight and total grain yield of finger millet

Table 1 presented results of the effect of rabbit manure (RM) and row arrangement (RA) on the spike weight, panicle weight and total yield of finger millet intercropped with groundnut at BUK and Dawakin Kudu. The result revealed that RM was significant at both locations. The application of RM at 2.5 t ha⁻¹ and NPK significantly (P < 0.05) produced the heaviest weight, though at par with 3.5 t ha⁻¹, while 0.0 t ha⁻¹ recorded the lightest weight at BUK. With the exception of 0.0 t ha⁻¹, which recorded the lowest result, all treatments at Dawakin Kudu were statistically equivalent and yielded the largest weight. At both locations, row arrangement and the interaction between row arrangement and rabbit manure did not significantly affect spike weight (P > 0.05).

The results further indicated that RM had a significant effect on the panicle weight at both locations. At BUK, the application of 1.5 t ha⁻¹ of RM and NPK significantly (P< 0.05) produced superior weight, though at par with 2.5 t ha⁻¹ and 3.5 t ha⁻¹ compared to 0.0 t ha⁻¹ that gave the least weight. At Dawakin Kudu, application of 2.5 and 3.5 t ha⁻¹ RM and NPK significantly (P < 0.05) produced the heaviest weight that was on par with 1.5 t ha⁻¹ RM while the least weight was recorded with 0.0 t ha⁻¹. RA and the interaction between RM and RA were not significant at both locations. The ability of RM to have a substantial impact on the spike, panicle weight, straw weight and total grain yield could be attributed to the fact that application of organic manure can improve soil enzymatic activity, soil microbial population structure and root respiration rate of crops, thus influencing its performance. Similar findings reported by



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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng Awopegba et al. (2024), corroborates our findings who claimed that rabbit manure application had a substantial impact on maize output. Jagadeesha et al. (2010), also reported that organic manure boosts the production of both grain and straw of finger millet. This was also due to the millet's needed absorption pattern, which required a slow and consistent release of nutrients into the soil solution. Furthermore, the higher concentrations of macro and micronutrients supplied to soil in the form of organic manure might have boosted nutrient availability in the root zone and nutrient uptake of finger millet, thereby leading to improved yield attributes of finger millet. These findings are also consistent with those of Zhang et al. (2020). However, the control (0.0 tha⁻¹ of RM) performed poorly in terms of finger millet yield, and yield components, which could be due to a lack of nutrient uptake because the plants had to rely on the soil's native fertility. Except for 0.0 t ha⁻¹ RM, which produced the least straw weight, the results showed that all of the treatments in both locations were statistically similar and significant (P < 0.05), recording heavier straw weight. RA had no significant (P > 0.05) impact in either location. In both cases, there was no significant (P > 0.05) impact between RA and RM. Similarly, the outcome demonstrated that RM had a substantial (P < 0.05) impact on 1000grain weight, with all treatments in BUK producing larger and statistically similar weights when compared to 0.0 t ha⁻¹, which produced the least weight. Nonetheless, at Dawakin Kudu, the use of NPK and RM at 1.5 tha⁻¹ resulted in superior weights comparable to 2.5 and 3.5 t ha⁻¹ ¹ as opposed to 0.0 t ha⁻¹, which had the lowest weight. At both sites, there was no significant (p > 0.05) influence on either RA or the interaction between RM and RA.

Additionally, the effect of RM and RA on the total grain yield of finger millet intercropped with groundnut at BUK and Dawakin Kudu showed that rabbit manure was only significant at Dawakin Kudu, where the application of 3.5 tha⁻¹ of rabbit manure and NPK significantly produced the highest grain yield, which was statistically similar with other treatments, while 0.0 tha⁻¹ resulted in a lower yield. The RA and the interaction between the two factors were not significant at both locations.

Intercrop row arrangement is an important management method that can improve radiation interception hence increasing intercrop yield (Onte *et al.*, 2019). The results on yield and yield components of finger millet as influenced by row arrangement revealed that all components were not significantly affected by row arrangement, which could be attributed to a reduction or absence of competition between the crops found in the mixture. Our findings conqur with those of Hamdallah and Ahmed (2010), who investigated the effects of wheat and bean planting patterns and discovered no significant difference between intercrops grown using different planting patterns. Similarly, Hussaini *et al.* (2001) also reported a no significant difference in crop proportions regardless of row arrangement.

Effect of Rabbit Manure and Row Arrangement on number of pods plant⁻¹, mean pod weight, fodder weight, 100 kernel weight and total kernel yield of groundnut

Table 2 also presented the result of number of pods of groundnut intercrop with finger millet at BUK and Dawakin Kudu. The result showed that number of pods of groundnut was significantly (P <0.05) affected by rabbit manure in which the application of NPK at both locations recorded the highest number of pods which was closely followed by 2.5 t ha⁻¹ in BUK, and Dawakin Kudu. Meanwhile the lowest number of pods was produced by the application of 0.0 tha⁻¹ of RM in both locations. Row arrangement did not significantly (P > 0.05) affect number of pods at both locations. The interaction between RM and RA on number of pods was significantly produced higher number of pods although at par with other interaction effects compared to 0.0 tha⁻¹ RM with 1:1 RA which had the lowest number of pods (Table 3).



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The significant and comparable effect of RM in producing higher number of pods at BUK and Daki Kudu, mean pod weight, 100 kernel weight at Dawakin Kudu could be related to the impact of RM of yield related attributes in improving the soi physical, chemical and biological properties thereby boosting crop production. This finding corroborates those of Onte *et al.* (2019) and Zhang *et al.* (2023) who reported separately the role of organic soil amendments in enhancing the microbial communities for food production. On a dry matter basis, rabbit manure is relatively rich in phosphorus and nitrogen when compared to other livestock manure (Siebielec *et al.*, 2023).

The effect of RM and RA on the mean pod weight of groundnut intercrop with finger millet at BUK and Dawakin Kudu is shown in Table 2. The result reveals that RM significantly affected mean pod weight at Dawakin Kudu where the application of NPK obtained superior mean pod weight over the other treatments but is statistically similar to 2.5 and 3.5 t ha⁻¹ of RM while the least weight was recorded with the application 0.0 t ha⁻¹ RA did not differ significantly (P < 0.05) due to mean pod weight. The interaction between RM and RA was significant at both locations. Table 4 shows the interaction of RM and RA on mean pod weight of groundnut in finger millet at BUK and Dawakin Kudu. Also, Sandborn (2016) stated that rabbit manure has a higher dry matter content than those of most farm animals. Animal manure application increased soil chemical characteristics significantly and regardless of manure type, soil accessible levels of N and P rose with increasing application rates (Gulshan *et al.*, 2013). Furthermore, Khoir *et al.* (2017) stated that Rabbit dung is one sort of organic material that can be used to boost plant production by improving the soil's physical, chemical, and biological qualities to boost crop yields. Hence, the use of manure is essential for intercropped plants' growth and development.

When row arrangement is considered under the application of 3.5 t ha⁻¹ PM applied to 2:2 RA it statistically produced the heaviest mean pod weight which was at par with other interaction effects compared to 0.0 t ha⁻¹ of RM applied to 1:1 RA, which resulted in the lowest mean pod weight at BUK. Similarly, at Dawakin Kudu, the result revealed that the heaviest mean pod weight was obtained under 2:1, 2:2, 2:4 RA treated with RM at 1.5 t ha⁻¹,2:1 and 2:2 RA treated with 2.5 tha⁻¹ of RM ¹ and 1:2 RA treated 3.5 tha⁻¹ and with NPK compared with rest of the interaction effects (Table 4).

The effect of RM and RA on fodder weight of groundnut intercropped with finger millet at BUK and Dawakin Kudu is presented in Table 2. The result showed that both RM, RA and the interaction between RM and RA did not significantly affect the fodder weight of groundnut at both locations. The insignificant effect of rabbit manure on fodder weight and kernel yield could be due to lack of/or reduced competition for nutrients between the component crops in the mixture. This could also be related to the nutrient benefit and contribution of organic manure's soil moisture retention potential.

The effect of RM and RA on the 100-kernel weight of groundnut intercropped with finger millet in BUK and Dawakin Kudu is presented in Table 2. It was observed that 100-kernel weight was significantly (P < 0.05) affected by RM only at Dawakin Kudu in which the application of NPK produced the heaviest weight which was at par with other rates of RM while 0.0tha⁻¹ recorded the least 100 kernel weight. The row arrangement did not vary significantly on the 100-kernel weight. However, the interaction between RM and RA was significant at both locations. This confirms the findings of Vandermeer (1992), who reported that when two crops are planted together, they will interact in either competition for (light, water, and nutrients) or facilitation. Because the taller millet crops do not fully utilize the incoming radiation, the canopy differences between millet and groundnut in the intercrop resulted in a greater improvement in radiation. Thus, groundnuts at a lower level make use of the light environment at the ground that would otherwise be wasted (Harris, 1990). The yield

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<u>ISSN (Print): 2651-6144; ISSN (Online): 2651-6365</u> Website: http://www.jasd.daee.atbu.edu.ng and yield components of groundnut were not affected by row arrangement. This could be due to intense competition for nutrients and other resources among component crops. This finding contradicts the claims of Zhao *et al.* (2022) that growth components directly increased groundnut yield. Similarly, it further disagrees with Dugje and Odo (2003), who reported that a 1:1 planting pattern resulted in a higher 1000-grain weight of groundnut intercropped with millet. This could be associated to lack of competition for resource utilization among the component crops. The findings also confirm that of Santo *et al.* (2023), which claimed that different row arrangements had no significant effect on groundnut yields.

Table 5 reveals the interaction of RM and RA on 100-kernel weight of groundnut in BUK and Dawakin Kudu. The RA of alternate stand and application of RM 3.5t ha⁻¹ significantly produced the heaviest weight which was comparable with other interaction combination compared to 2:2 RA combined with 1.5 tha⁻¹ of RM that resulted in lowest weight at BUK. However, at Dawakin Kudu, the application of 2:1 RA combined with 0.0 tha⁻¹ significantly recorded the lowest 100 kernel weight compared with other interaction combination that resulted in higher 100 kernel weight.

The effect of rabbit manure and row arrangement on kernel yield of groundnut intercropped with finger millet in BUK and Dawakin kudu is shown in Table 2. The application of RM, RA and the interaction between RM and RA on kernel yield of groundnut did not vary significantly (P < 0.05) at both locations.

Harvest index and Land equivalent ratio

Table 6 presented result of the influence of RM and RA on harvest index (HI) and Land equivalent ratio (LER) of groundnut intercropped with finger millet at BUK and Dawakin Kudu. Result reveals that HI did not significantly (P >0.05) vary due to application of RM and RA. Similarly, just like with yield, results for Land Equivalent Ratio (LER) showed intercropping to be more productive than sole cropping (Table 6). At BUK, the combination of equal parts finger millet and groundnut rows (1:1) with a moderate application of rabbit manure (2.5 t/ha) produced the highest LER (3.04). This was comparable to the LER achieved with other planting patterns like 2:2 rows, alternating rows (AS), and 2:1 row. In Dawaki, the 1:2 finger millet to groundnut row arrangement yielded the highest LER, closely followed by the 2:1, 2:2, and 2:4 arrangements. Notably, most combinations at both locations had LER values exceeding 1. This indicates that intercropping allows the component crops (finger millet and groundnut) to effectively utilize available growing resources. Land ratio (LER) is a criterion for evaluating crop productivity in intercropping systems, and it demonstrates how efficient intercropping is in utilizing environmental resources when compared to sole cropping (Bantie et al. 2014). On a world-wide basis, Martin-Guay et al. (2018) found that the average LER was 1.30, 95% CI (1.27, 1.32).

The value of the treatments in this study was greater than one, indicating that intercrops use land more efficiently than solitary crops. Rabbit manure at 3.5t ha⁻¹ at BUK and 2.5 t ha⁻¹, and row arrangement 1:1 at BUK and 1:2 at DKD produced the highest LER. This could be as a result of efficient N₂ fixation by the groundnut and subsequent absorption by the finger millet. According to Osang *et al.* (2004), LER values in maize/soybean mixtures are frequently higher than one. Furthermore, Liu *et al.* (2006), affirms that the productivity of an intercrop system compared to a single crop may have resulted from the complementary and efficient utilization of growing resources by the component crops.

CONCLUSION AND RECOMMENDATIONS

From the result of this study, it could be deduced that rabbit manure (RM) application significantly affected most of the measured parameters of finger millet and groundnut, with the exception of row arrangement (RA), which generally had no significant effect. The most



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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng effective rate of RM application depended on the specific parameter and location. For finger millet, application of RM increased spike weight, panicle weight, 1000-grain weight, and total grain yield at Dawakin Kudu but only affected spike weight at BUK. For groundnut, RM application increased the number of pods per plant, mean pod weight, and 100-kernel weight at Dawakin Kudu, while only affecting the number of pods per plant at BUK. Therefore, it could be recommended for farmers in the Sudan savanna to consider the possible adoption of the application of rabbit manure at a rate of 2.5–3.5 t ha⁻¹ to increase finger millet and groundnut yields, especially at Dawakin Kudu. Since row arrangement appears to have minimal impact on finger millet and groundnut yields, it may be suggested that the farmer should practice the row arrangement that appeared to have better ease of harvest as well as good price forecast, and family needs of the two crops.





Table 1: The effect of rabbit manure and row arrangement on the spike weight, panicle weight, straw yield, 1000 grain weight and grain yield of finger millet intercropped with groundnut at BUK and Dawakin Kudu

Treatment	Spike	weight	Panicle	weight	Strav	v yield	1000 gra	in weight	Grair	n yield
_	()	g)	(Kg	ha ⁻¹)	(Kg	ha ⁻¹)	(g)	(Kg	ha ⁻¹)
	BUK	DWK	BUK	DWK	BUK	DWK	BUK	DWK	BUK	DWK
Rabbit Manure (RM)	<u>(t ha⁻¹)</u>									
0.0	37.88c	20.92b	155.18b	123.55b	0.43b	0.58b	1.36b	1.36b	232.45	206.01b
1.5	43.98b	33.83ab	295.80a	209.60ab	1.17a	1.18a	2.07a	2.04a	409.87	369.69ab
2.5	62.55a	35.58a	251.93ab	260.04a	0.82a	1.06a	1.78a	1.71ab	483.09	375.56ab
3.5	53.85ab	31.27ab	249.46ab	227.91a	0.98a	1.08a	1.83a	1.75ab	591.85	486.74a
NPK	65.47a	28.15ab	333.273a	274.92a	1.02a	1.11a	1.99a	1.86a	590.83	483.70a
P-value	0.007	0.0143	0.043	0.014	0.003	0.035	0.004	0.023	0.050	0.028
SE±	6.085	28.94	41.33	32.399	0.135	0.145	0.135	0.145	23.299	19.351
Row arrangement (R.	<u>A)</u>									
1:1	50.81	31.23	231.28	196.67	0.78	0.94	1.95	1.76	109.37	106.53
1:2	52.06	30.23	233.79	221.19	0.70	0.91	1.85	1.83	104.73	120.94
2:1	68.25	27.83	338.47	194.44	1.14	0.88	1.97	1.89	191.73	103.03
2:2	51.47	27.39	277.59	190.03	1.29	0/87	1.76	1.70	132.88	102.39
2:4	50.20	31.28	246.05	192.63	0.66	0.92	1.67	1.61	119.51	99.52
AS	51.28	31.14	212.49	205.27	0.69	1.15	1.73	1.71	102.77	109.03
P-value	0.283	31.54	0.572	0.434	0.100	0.677	0.788	0.785	0.416	0.316
SE±	7.697	3.986	52.28	40.982	0.171	0.183	0.171	0.183	29.471	24.477
Interaction										
RM x RA	0.501	0.990	0.779	0.250	0.324	0.235	0.197	0.450	0.716	0.375

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK. AS= alternate stand.





 Table 2: The effect of rabbit manure and row arrangement on number of pods plant⁻¹, mean pod weight, fodder weight, 100 kernel weigh and kernel

 ______yield of groundnut intercropped with finger millet at BUK and Dawakin Kudu

Treatment	Number of pods		Mean pod weight		Fodder weight		100 kernel weight		Kernel yield	
_	pla	nt ⁻¹	(1	kg)	(Kg	ha ⁻¹)	((g)	(Kg	ha ⁻¹)
	BUK	DWK	BUK	DWK	BUK	DWK	BUK	DWK	BUK	DWK
Rabbit Manure (RM) (1	<u>ha⁻¹)</u>									
0.0	25.83b	26.88c	15.89	25.83c	0.78	0.64	25.42	24.50c	214.57	229.48
1.5	29.88ab	29.00bc	13.90	26.50bc	0.71	0.67	21.73	26.63bc	171.30	216.70
2.5	30.75ab	34.25ab	16.22	30.75ab	0.76	0.76	24.66	30.94ab	175.68	228.94
3.5	26.50b	31.58abc	13.58	29.88abc	0.65	0.54	21.11	29.23abc	201.73	189.00
NPK	33.83a	36.13a	17.48	33.83a	0.84	0.79	27.78	32.61a	270.78	238.37
P-value	0.046	0.025	0.119	0.046	0.668	0.345	0.076	0.034	0.211	0.774
SE±	2.051	2.186	1.194	0.299	0.092	0.092	1.852	1.966	32.726	28.726
Row arrangement (RA)	<u>)</u>									
1:1	33.40	33.73	17.67	34.40	0.67	0.51	29.23	30.75	269.16	205.86
1:2	29.00	32.20	14.59	29.00	0.72	0.67	23.17	29.05	167.00	210.38
2:1	31.80	34.73	15.72	31.80	0.76	0.71	23.33	31.54	128.24	234.73
2:2	27.20	27.33	14.87	27.20	0.77	0.54	23.08	25.61	282.33	190.91
2:4	25.67	29.07	13.29	25.67	0.87	0.77	21.26	26.39	200.57	264.56
AS	33.13	33.20	17.08	33.13	0.75	0.79	25.83	29.82	193.67	232.89
P-value	0.096	0.381	0.285	0.096	0.864	0.252	0.214	0.508	0.101	0.170
SE±	2.595	2.765	1.510	1.643	0.117	0.117	2.342	2.487	9.395	8.336
Interaction										
RM x RA	0.004	0.013	0.029	0.004	0.066	0.093	0.029	0.004	0.431	0.098

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK. AS= alternate stand.

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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng Table 3: Interaction of rabbit manure and row arrangement on the number of pods of

ground	nut i	intercro	pped [•]	with	finger	millet i	n BUK	

	Rabbit Manure (t ha ⁻¹)								
Row Arrangement	0.0	1.5	2.5	3.5	NPK				
1:1	3.55e	23.67a-d	34.00abc	34.67abc	37.33ab				
1:2	33.00abc	24.00a-d	34.33abc	23.67a-d	30.00abc				
2:1	32.67abc	36.00abc	31.00abc	23.67a-d	35.67abc				
2:2	35.67abc	37.33ab	29.67abc	37.67a	33.00abc				
2:4	8.67de	30.00abc	37.33ab	34.00abc	35.67abc				
AS	20.00cd	35.33abc	34.33abc	23.00a-d	35.67abc				
SE±			5.802						

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK. AS= alternate stand

Table 4: Interaction of rabbit manure and row arrangement on the mean pod weight of groundnut intercropped with finger millet at BUK and DWK during 2019 season

	Rabbit manure (t ha ⁻¹)							
Row Arrangement	0.0	1.5	2.5	3.5	NPK			
			<u>BUK</u>					
1:1	0.00f	13.70а-е	17.73abc	16.27abc	20.43ab			
1:2	16.27abc	13.20а-е	16.47abc	11.70b-e	15.30a-d			
2:1	18.90abc	17.20abc	15.43a-d	11.97b-e	15.10a-d			
2:2	16.97abc	20.20ab	16.97abc	21.63a	18.77abc			
2:4	6.37def	13.93а-е	10.27cde	18.13abc	17.73abc			
AS	18.50abc	19.87ab	18.23abc	11.20b-e	17.60abc			
SE±			0.196					
			Dawakin Kudu					
1:1	21.80ab	15.17abc	20.93ab	20.57ab	21.63ab			
1:2	15.13abc	15.27abc	21.50ab	22.83a	22.93a			
2:1	21.30ab	33.53a	23.03a	15.13abc	22.33ab			
2:2	20.27ab	23.47a	20.23ab	22.53a	20.53ab			
2:4	7.13cd	22.80a	13.93abc	20.73ab	20.63ab			
AS	5.33d	21.80ab	18.93ab	13.40abc	20.70ab			
SE±			3.674					

Means followed by the same letter(s) across column and rows are not significantly different at 5% level of probability using SNK. Alternate stand



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Table 5: Interaction of rabbit manure and row arrangement on the 100-kernel of

groundnut in groundnut intercropped with finger millet at BUK and Dawakin kudu

	Rabbit manure (t ha ⁻¹)							
Row arrangement	0.0	1.5	2.5	3.5	NPK			
			<u>BUK</u>					
1:1	16.33def	21.63a-f	29.33a-d	29.87a-d	32.07ab			
1:2	26.93a-d	19.73a-f	23.40а-е	20.47a-f	25.33a-d			
2:1	28.80a-d	25.33a-d	22.77а-е	17.07c-f	22.67а-е			
2:2	29.60a-d	4.00g	24.60а-е	29.97a-d	32.23abc			
2:4	10.00efg	22.10a-f	16.83c-f	29.43a-d	27.93a-d			
AS	28.77a-d	30.63a-d	27.57a-d	33.23a	25.83a-d			
SE±			5.237					
			<u>Dawakin Kudu</u>					
1:1	32.77a	23.17ab	31.90a	32.77a	33.17a			
1:2	32.83a	23.03ab	33.13a	23.30ab	33.97a			
2:1	6.07c	31.70a	33.73a	22.83ab	34.57a			
2:2	32.63a	34.87a	31.77a	33.77a	29.90a			
2:4	10.83bc	36.33a	21.03b	31.97a	31.77a			
AS	34.90a	32.07a	29.30a	21.03	31.80a			
SE±			5.561					

Means followed by the same letter(s) across column and rows are not significantly different at 5% level of probability using SNK. Alternate stand

Treatment	BUK	DWK	BUK	DWK
	Harves	Land equivalent ra		
Rabbit manure (RM) (t ha ⁻¹)				
0.0	0.75	0.99	2.80	2.06
1.5	0.57	0.77	1.93	1.96
2.5	0.60	0.82	2.25	2.24
3.5	0.66	0.71	1.74	1.74
NPK	0.76	0.73	1.60	2.33
P-value	0.080	0.059	0.398	0.839
SE±	0.6007	0.336	0.388	0.564
tow arrangement (RA)				
:1	0.93	0.99	3.04	1.69
:2	0.52	0.72	1.79	2.82
:1	0.48	0.87	2.11	2.79
::2	0.90	0.83	2.77	2.54
2:4	0.51	0.82	1.33	2.09
AS	0.65	0.82	2.69	1.64
P-value	0.131	0.129	0.185	0.177
SE±	0.097	0.470	0.597	0.487
nteraction				
XM x RA	0.024	0.052	0.762	0.066

Table 6: The harvest index and land equivalent ratio of finger millet intercropped with	
menn dant as affected by usbit meaning and your among any of DUV and Danish	

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK. AS= alternate stand.



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REFRENCES

- African Institute of Corporate Citizenship. (2016). Malawi Groundnut Outlook. TAURUS House Executive Offices City Centre, Along Convention Drive P/Bag 382 Lilongwe 3 Malawi.
- Adhikary, S. P. and Gantayet, P. K. (2012). Studies on the influence of organic fertilizers on the growth and some biochemical parameters of chilli (*Capsicum annum* L.). *Journal of Biological Sciences*. 7(2):255-258.
- Asseng, S., Zhu, Y., Basso, B., Wilson, T. and Cammarano, D. (2014). Simulation Modeling: Applications in Cropping Systems, Editor(s): Neal K. Van Alfen, Encyclopedia of Agriculture and Food Systems, Academic Press, Pages 102-112. <u>https://doi.org/10.1016/B978-0-444-52512-3.00233-3</u>
- Awopegba, T. M., Adeboye, K. A. and Samuel, F. F. (2024). The Effects of Rabbit Compost Fertilizer on the Growth Parameters of Maize (Zea mays L.). *Turkish Journal of Agriculture-Food Science and Technology*, **12**(6):899-904.
- Awol, A., Masresha, F. and Kassahun, T. (2013). Agro morphological, physiological, and yield related performances of Finger Millet [*Eleusine coracana* (L.) Gaertn.] Accessions evaluated for drought resistance under field condition, *Asian Journal of Agriculture and Rural Develeopment*, 3(10):709–720.
- Bantie, Y. B., Abera, F. A. and Woldegiorgis, T. D. (2014). Competitive Indices of Intercropped Lupine (Local) and Small Cereals in Additive Series in West Gojam. North Western Ethiopia. *American Journal of Plant Sciences*, 5: 1296-1305. <u>http://dx.doi.org/10.4236/ajps.2014.59143</u>
- Brooker, R.W., Bennett, A.E., Cong, W., Daniell, T. J., George, T. S., Hallett, P. D., Hawes, C., Iannetta, P. M. P., Jones, H. G., Karley, A. J., Li, L., McKenzie, B. M., Pakeman, R. J., Paterson, E., Schob, C., Shen, J., Squire, G., Watson, C.A., Zhang, C., Zhang, F., Zhang, J. and White, P. J. (2014). Improving intercropping: A synthesis of Research in Agronomy, Plant Physiology and Ecology. *Research Review*, 206: 107-117. https://doi.org/10.1111/nph.13132
- Chamkhi, I., Cheto, S., Geistlinger, J., Zeroual, Y., Kouisni, L., Bargaz, A. and Ghoulam, C. (2022). Legume-based intercropping systems promote beneficial rhizobacterial community and crop yield under stressing conditions. *Industrial Crops and Products*, **183**: 114958, ISSN 0926-6690, <u>https://doi.org/10.1016/j.indcrop.2022.114958</u>
- Chetan, S. and Mellashi, N. G. (2007). Finger millet polyphenols: characterization and their nutraceutical potential, *American Journal of Food Technology*, **2**(7):582-592.
- Coulibaly, M. A., Ntare, B. R., Gracen, V. E., Danquah, E. and Ofori, K. (2017). Groundnut production constraints and farmers' preferred varieties in Niger. *International Journal of Innovative Science, Engineering* & Technology, 4(1): 202-207.
- Daryanto, S., Fu, B., Zhao, W., Wang, S., Pierre-André, J. and Wang, L. (2020). Ecosystem service provision of grain legume and cereal intercropping in Africa. Agricultural Systems, 178: 102761, <u>https://doi.org/10.1016/j.agsy.2019.102761</u>
- Dhima, K. V., Lithourgidis, A. S., Vasilakoglou, I. B. and Dordas, C. A. (2007). Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Research*, **100**(2-3): 249-256.
- Dugje, I. Y. and Odo, P. E. (2003). Effects of Planting Patterns on the Performance of Pearl Milllet- Groundnut Intercrop in the Sudan Savanna of Nigeria. Nigerian Journal of Experimental and Applied Biology, 4(2): 239-245
- FAOSTAT (2012) Food and Agricultural Organization of the United Nations Data. Statistical Database. http://faostat.fao.org/default.aspx?lang=en
- FFD., (2012) Fertilizer Use and Management Practices for Nigeria. Federal Fertilizer Department. Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria, pp: 1-215.
- Gitari, H. I., Nyawade, S. O., Kamau, S., K Gachene, C. K., Karanja, N. N., and Schulte- Geldermann, E. (2019). Increasing potato equivalent yield increases returns to investment under potato-legume intercropping systems. *Open Agriculture*, 4(1):623-629. <u>https://doi.org/10.1515/opag-2019-0062</u>
- Gulshan, A. B., Saeed, H. M., Javid, S., Meryem, T., Atta, M. I. and Amin-ud-Din, M. (2013). Effects of animal manure on the growth and development of okra (*Abelmoschus esculentus* L.). ARPN *Journal of Agricultural and Biological Science*, 8(3):213-218.
- Hamdallah, E. and Ahmad, G. (2010). Effects of Different Planting Pattern of Wheat (*Triticum aestivum*) and Bean (*Vicia faba*) on Grain Yield, Dry Matter and Weed Biomass. Notulae Scintia Biologue, 2(4):111– 115. <u>https://doi.org/10.15835/nsb244824</u>
- Harris, P. M. (1990). Potato Crop Radiation Use: A Justification for Intercropping. *Field Crop Research*, **25**: 25-39.
- Haruna I. M., Aliyu L., Olufaju O. O. and Odion E. C. (2011) Growth of Sesame (Sesamum Indicum L.) as Influence by Poultry Manure, Nitrogen and Phosphorus in Samaru, Nigeria. American-Eurasian Journal of Scientific Research, 10: 56-568



Volume 7, Number 3, September, 2024

ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng

- Hussaini, M. A., Ahmad, A. and Mahmud, M. (2001). Productivity of Maize/Groundnut mixture as Influenced by Row Arrangement and Crop Proportion. *Journal of Agriculture and Environment*,**2**: 221-231.
- Jaiswal, J. K., Levini, L. A. and Dakora, F. D. (2017). Phylogenetically diverse group of native bacterial symbionts isolated from root nodules of groundnut (*Arachis hypogaea* L.) in South Africa. Systematic and Applied Microbiology, 40: 215–226. doi: 10.1016/j.syapm.2017.02.002
- Jagadeesha, N., Reddy, V. C., Krishnamurthy, N. and Sheshadri, T. (2010) Effects of Organic Manure on Productivity of Finger Millet and Redgram Intercropping System Under Protective Irrigation. International Journal of Agricultural Sciences, 6 (2):453-455.
- Jemo, M., Devkota, K. P., Epule, T. E., Chfadi, T., Moutiq, R., Hafidi, M., Silatsa, F. B. T. and Jibrin, J. M. (2023). Exploring the potential of mapped soil properties, rhizobium inoculation, and phosphorus supplementation for predicting soybean yield in the savanna areas of Nigeria. *Frontiers in Plant Science*, 14: 1120826. <u>https://doi.org/10.3389/fpls.2023.1120826</u>
- Jayawardana, S. A. S., Radhi Samarasekera, J. K. R. R., Hettiarachchi, G. H. C. M. and Gooneratne, M. J. (2022). Antidiabetic properties of finger millet (*Eleusine coracana* L.) Gaertn.) varieties cultivated in Sri Lanka. *Journal of Herbal Medicine*, **32**: 100534, <u>https://doi.org/10.1016/j.hermed.2022.100534</u>
- Kermah, M., Franke, A. C., Adjei-Nsiah, S., Ahiabor, B. D. K., Abaidoo, R. C. and Giller, K. E. (2018). N₂-fixation and N contribution by grain legumes under different soil fertility status and cropping systems in the Guinea savanna of northern Ghana. *Agriculture, Ecosystems and Environment*, **261**: 201-210. https://doi.org/10.1016/j.agee.2017.08.028
- Khoir, M. S., Herlina, N., Koesriharti, B. and Santoso, M. (2017). Effect of NPK Fertilizer and Rabbit Manure compost on Growth and Yield of Carrot (*Daucus carota* L.). *Journal of Plant Production*, 5(6):1029-1034.

Kolawole, G. O., and Ajibola A. T. (2019) Nutrient Management in Maize-Sesame Intercropping System. *Research on Crops*, **20**(3):495-500.

Li, C., Stomph, T., Makowski, D., Li, H., Zhang, C., Zhang, F., and van der Werf, W. (2023). The productive performance of intercropping. Proceedings of the National Academy of Sciences. Edited by David Tilman, University of Minnesota College of Biological Sciences, St. Paul, MN <u>https://doi.org/10.1073/pnas.2201886120</u>

Liu, J. H., Zeng, Z. H., Jiao, L. X., Hu, Y. G., Wang, Y., and Li, H. (2006). Intercropping of Different Silage Maize Cultivars and Alfalfa. *Acta Scientiarum Agronomy*, **32**: 125-130.

- Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., Brahmachari, K., Shankar, T., Bhadra, P., Palai, J.B., Jena, J., Bhattacharya, U., Duvvada, S.K., Lalichetti, S. and Sairam, M. (2021). Intercropping—A Low Input Agricultural Strategy for Food and Environmental Security. Agronomy, 11: 343. <u>https://doi.org/10.3390/agronomy11020343</u>
- Manasa, P., Maitra, S. and Reddy, M. D. (2018). Effect of summer maize-legume intercropping system on growth, productivity and competitive ability of crops. *International Journal of Management*, *Technology and Engineering*, 8: 2871–2875.
- Martin-Guay, M. O., Paquette, A., Dupras, J. and Rivest, D. (2018). The new green revolution: sustainable intensification of agriculture by intercropping. *Science Total* Environment, **615**: 767–772.
- Onte, S., Singh, M., Meena, V., Kumar, S., Meena, B. L., and Dutta, S. (2019). Organic Nutrient Management in Context to Sustainable Fodder Production: A Review. *International Journal of Current Microbiology and Applied Sciences*, 8: 2434-2449. 10.20546/ijcmas.2019.809.282
- Osang, P. O., Richard, B. I. and Iheadindueme, C. A. (2004) Influence of Date of Planting and Time of Introduction of Maize on the Agronomic Performance of Soybean-Maize Intercrop in Nigerian Southern-Guinea Savanna. *Journal of Biology, Agriculture and Healthcare,* **4**(3):136-143.
- Sandborn, D. (2016). Bunny honey: Using rabbit manure as a fertilizer. Michigan State University Extension Bulletin.
- Santo, K. G., Bugilla, F. B., Khalid, A. A., Atakora, K., Abdulai, M., Afreh, D. N. and Norshie, P. M. (2023). Performance of Maize (Zea mays L.) and Land Equivalent Ratio under Maize-Groundnut (*Arachis hypogea* L.) Intercropping System. *Agricultural Sciences*, 14: 1292-1320.
- Shehu, B. M., Jibrin, J. M. and Samndi, A. M. (2015). Fertility Status of Selected Soils in the Sudan Savanna Biome of Nigeria. *International Journal of Soil Science*, **10**: 74-83. <u>https://doi.org/10.3923/ijss.2015.74.83</u>
- Siebielec, S., Marzec-Grządziel, A., Siebielec, G., Ukalska-Jaruga, A., Kozieł, M., Gałązka, A., Przybyś, M., Sugier, P. and Urbaniak, M. (2023) Microbial Community Response to Various Types of Exogenous Organic Matter Applied to Soil. *International Journal of Molecular Sciences*, 24(19): 14559. doi: 10.3390/ijms241914559.

Volume 7, Number 3, September, 2024

ISSN (Print): 2651-6144; ISSN (Online): 2651-6365 Website: http://www.jasd.daee.atbu.edu.ng

Takim, F. O. (2012). Advantages of maize-cowpea intercropping over sole cropping through competition indices. *Journal of Agriculture and Biodiversity Research*, 1(4): 53-59.

- Thilakarathna, S. and Raizada, N. (2015). A review of nutrient management studies involving finger millet in the semi-arid tropics of Asia and Africa: Review. *Agronomy*, **5**: 262–290.
- Vandermeer, J. H. (1989). The Ecology of Intercropping. Cambridge Uni. Press. Cambridge, UK.

Vandermeer, J. H. (1992). The Ecology of Intercropping. Cambridge Uni. Press. Cambridge, UK.

- Variath, M. T. and Janila, P. (2017). Economic and Academic Importance of peanut. In: Varshney R, Pandey M, Puppala N, Editors. The peanut genome. *Compendium of Plant Genomes*. Cham: Springer. doi:10.1007/978-3-319-63935-2 2.
- Zhang, X., Li, J., Shao, L., Qin, F., Yang, J., Gu, H., Zhai, P. and Pan, X. (2023). Effects of organic fertilizers on yield, soil physico-chemical property, soil microbial community diversity and structure of Brassica rapa var. Chinensis. *Frontiers of Microbiology*, 14:1132853. doi: 10.3389/fmicb.2023.1132853.
- Zhao, X., Dong, Q., Han, Y., Zhang, K., Shi, X., Yang, X., Yuan, Y., Zhou, D., Wang, K., Wang, X., Jiang, C., Liu, X., Zhang, H., Zhang Z. and Yu, H. (2022). Maize/peanut intercropping improves nutrient uptake of side-row maize and system microbial community diversity. *BMC Microbiology*, 22: 14. https://doi.org/10.1186/s12866-021-02425-6.