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# Optimization of Maize-Vegetable (Okra and Roselle) Intercrops in Northern, Upper West and Upper East Regions of Ghana

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**Abstract:** Intercropping as a practice is very crucial in livelihood sustainability among smallholder farming communities in many growing countries. However, for most cropping systems, the benefits of intercropping have yet to be optimized due to a lack of knowledge regarding spatial arrangements and planting densities. The objective of the study was to find out the profitability of maize-vegetable intercropping and the yields obtained from various spatial arrangements and planting densities of intercrops. From May to October 2019 and 2020 respectively, Experimental trials were set up in the rainy season in Northern, Upper West and Upper East regions of Ghana comprising of eight treatments each. A randomized complete block experimental design was used for the field layout with three to four replications. Data was collected on grain and fruit yield and land equivalent ratios was estimated (LER). At the end of the trial, important spatial arrangements and planting densities were identified that can be adopted by smallholder famers for system intensification. For okra, the optimal intercropping system under sufficient rainfalls was 2 okra rows at higher density and 2 maize rows at lower density for Upper West Region. In Upper East Region, the optimal spatial arrangement to recommend is 1 row of maize at recommended density: 2 rows of okra at lower density under well distributed rainfalls. For roselle, intercropping with spatial arrangement of 2 rows of maize at higher density: 1 row of okra at recommended density was recommended in Northern Region.

**Keywords:** maize; okra; roselle; intercrops; sole crop; land equivalent ratios; productivity

## 1. Introduction

Farmers employ vegetable-maize intercropping to address subsistence and commercial objectives because it ensures constant yield at low risk levels [1,2]. Food can be ensured in the event of crop failure because there is always another crop to harvest [3]. Farmers' social and economic requirements are met by intercropping, and the technology can boost small-scale farmers' production.

The technology of intercropping is mostly practiced in many developing countries within their subsistence and food production farming systems [4]. Maize (Zea mays L.) is commonly intercropped with other crops during the wet season in the Guinea savanna of Northern Ghana. Maize is commonly intercropped with Soybeans [5,6], fruit crops [7], and vegetables [7-9]. Vegetables such as tomato, African Eggplant, roselle, amaranthus, Okra and hot pepper are the most common vegetable crops for maize-vegetable intercrop in Ghana during the wet season.

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The prevalence of Insect pests and related diseases cause more damage in solitary cropping systems than in intercropping systems. Aphid and thrips populations are greatly reduced in the cowpea-sorghum intercrop [10]. In chili-maize [11] and tomato-maize [12], pest and disease pressure is moderate. Intercropping minimizes the amount of work and inputs needed to protect crops from pests and diseases.

Intercropping can sometimes result in beneficial physiological interactions. For example, when population density is combined with sorghum-soybean intercrops, soybean seed protein increases [13]. It is possible that the two crops have a symbiotic connection in which intercropping reduces soil erosion by providing adequate soil coverage [14]. Negative interactions are possible; for example, the release of allelopathic phenolic chemicals into the soil by the sorghum variety CE145-66 had a negative effect on groundnut inter-crops [15].

In order for farmers to embrace improved intercropping systems, they must be more productive than conventional intercropping or sole cropping. Some writers suggested that the assessment of the two intercropped system may be based on a common unit [4]. Land use intensity, constituent productivity, and investment returns are all factors to consider are all factors considered in developing a technique for quantifying the productivity of intercropped species [16]. The land equivalent ratio (LER) was established by Willey [16] to be the sum land area required in a single cropping system to attain good performance interms of yield as comparable to a system of polyculture. [17] assessed the economic income of the two techniques in cereal-cowpea intercrops using the land equivalent ratio. If the gross return/ha of intercropping exceeds the gross return/ha of a single crop, intercropping is favored. In terms of LER, intercropping maize with soybeans yielded a larger yield advantage than an individual crop [18].

However, due to a lack of understanding about spatial arrangements and planting densities, the gains of intercropping have yet to be maximized for most cropping systems. Our research aims to (I) measure the productivity of the vegetable-maize intercropping system in three administrative regions of Northern Ghana, and (II) assess the impact of spatial arrangements and planting densities of maize-vegetable intercrops on the production of both crop species.

## 2. Materials and Methods

Trials were prepared and conducted in the Upper West Region (UWR), Northern (NR) and Upper East (UER) parts of Ghana during the rainy season in 2019 and 2020, which lasted from May to October. A single replication of eight treatments was created by each test or test farmer. Three replications of these treatments, which were a mix of spatial layouts and planting density, were examined in the vegetable-maize intercropped trials.

### *2.1. Planting Densities For Maize And Vegetables During 2019 And 2020 Humid Seasons In Ghana*

The treatments for spatial arrangements x planting density included (I) sole vegetable at the region's recommended planting density, (ii) sole maize at the region's recommended planting density (67,000 plants/ha), (iii) sole vegetable at low planting density, and (iv) pure maize at high planting density (133,000 plants/ha). (v) 1 row of maize at the recommended planting density and 1 row of vegetable at the recommended planting density, (vi) 1 row of maize at the recommended planting density and 2 rows of vegetable at low planting density, (vii) 2 rows of maize at high planting density and 1 row of vegetable at the recommended planting density, (viii) 2 rows of maize at high planting density and 2 rows of vegetable at low planting density

### *2.2. Genetic materials*

Okra (Abelmoschus esculentus) and roselle were the vegetable crops employed in this study (Hibiscus sabdarifa). Each farmer was treated as a replication and was subjected to eight different treatments. The maize variety planted was 'Abontem.' The vegetable

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varieties were (I) Clemson spineless okra and (ii) local variety roselle. Okra and roselle seeds were planted directly. Dressed seeds were spread at a depth of 2-3 cm before mulching. All of the intervention communities' experimental plots were ploughed with a tractor and harrowed. The researchers utilized a randomized complete block design (RCBD) and the size of the plot was 9 m × 4 m. Eight treatments and three or four replications were used in each experiment. Both maize and vegetables received a basal compound fertilizer (15N:15P:15K). 5-6 weeks after sowing, top-dressing was applied to all crops with sulphate of ammonia. At 2 and 5 weeks following planting, the plots were hand-weeded. Grain and fresh fruit weight were collected for maize and vegetables, respectively. Dry calyx weight was one of the measurements taken on roselle.

### *2.3. Statistical analysis*

The treatments of spatial arrangements x planting density was compared using GenStat Edition 17th. To determine how beneficial intercropping was in comparison to pure stand farming, land equivalent ratio (LER) was utilized. For mean yield separation at a 95 percent confidence interval, the Least Significant Difference (LSD) test procedure in GenStat Edition 17th was utilized. [Maize intercropped * (Maize Pure stand) -1] + [Vegetable Intercropped * (Vegetable Pure stand)-1] = LER. The calculation of these numbers was done using the region's means for a certain intercropped system. A LER value larger than 1 indicated a synergistic interaction (beneficial intercrop), whereas an LER value less than 1 exhibited an adversarial relationship (pure stand cultivation was more productive than intercropping).

## 3. Results

### *3.1. Optimized Spatial Arrangement X Planting Density For Okra-Maize Intercrops In Three Regions Of Ghana*

In 2020, the treatments of spatial arrangements x density for okra ($p>0.69$) and maize ($p>0.076$) in the UWR were not significant. For all intercrops, the land equivalent ratio (LER) was 1 (Table 1). The treatment with two greater density okra rows and two lower density maize rows had the highest LER (2.12).

**Table 1.** Yields (kg/ha) and land equivalent ratios (LER) of okra and maize in the intercropped farm fields under different planting densities in Upper West Region (UWR) of Ghana during 2020 humid season.

| | | UWR 2020 | | |
|---|---|---|---|---|
| Plant density | Spatial arrangement | Okra | Maize | LER |
| Maize (67,000) | PSR[1] | | 2694 | |
| Maize (133,000) | PSH[2] | | 2883 | |
| Okra (56,000) | PSR[1] | 2156 | | |
| Okra (37,000) | PSL[3] | 1306 | | |
| Maize (67,000) + Okra (56,000) | 1MR[4] : 1EPR[5] | 1397 | 2939 | 1.67 |
| Maize (67,000) + Okra (37,000) | 1MR[4] : 2EPL[6] | 1403 | 1464 | 1.58 |
| Maize (133,000) + Okra (56,000) | 2MH[7] : 1EPR[5] | 1726 | 2694 | 1.80 |
| Maize (133,000) + Okra (37,000) | 2MH[7] : 2EPL[5] | 1406 | 2822 | 2.12 |
| LSD | | *NS* | *NS* | |

**P < 0.05;**P < 0.01; NS: ANOVA not significant with 95% confidence interval.*

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Eggplant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density

In 2020, the effects of treatments of spatial arrangements x density on okra-maize intercrops in the UER were not significant for okra ($p>0.052$) but were significant for maize (p>0.003). Sole maize grown at the specified density yielded more (2,416 kg/ha) than sole maize grown at a higher density and all intercropped maize treatments. For treatments of 1 row of maize at acceptable density, the land equivalent ratio (LER) was 1: 2 rows of okra at reduced density and 1 row of corn at recommended density: 1 row of okra at recommended density and 1 row of maize at recommended density

**Table 2.** Yields (kg/ha) and land equivalent ratios (LER) of okra and maize in the intercropped farm fields under different planting densities in Upper East Region (UER) of Ghana in 2020 humid season.

| | | | UER 2020 | |
|---|---|---|---|---|
| Plant density | Spatial arrangement | Okra | Maize | LER |
| Maize (67,000) | PSR[1] | | 2416 | |
| Maize (133,000) | PSH[2] | | 1834 | |
| Okra (56,000) | PSR[1] | 2346 | | |
| Okra (37,000) | PSL[3] | 2950 | | |
| Maize (67,000) + Okra (56,000) | 1MR[4] : 1EPR[5] | 1273 | 1167 | 1.18 |
| Maize (67,000) + Okra (37,000) | 1MR[4] : 2EPL[6] | 2079 | 898 | 1.19 |
| Maize (133,000) + Okra (56,000) | 2MH[7] : 1EPR[5] | 687 | 1685 | 0.99 |
| Maize (133,000) + Okra (37,000) | 2MH[7] : 2EPL[5] | 850 | 998 | 0.70 |
| *LSD* | | *NS* | 657.3** | |

*$P$ < 0.05;***P* < 0.01; *NS:* ANOVA not significant with 95% confidence interval.

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Eggplant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density.

The influence of spatial arrangements was significant for okra (p=0.006) and maize (p=0.001) in the NR in 2019, but not for okra (p=0.117) or maize (p=0.192) in 2020. (Table 3). Sole maize and sole okra treatments always yielded more than intercropped maize and intercropped okra treatments, respectively. Only one treatment in NR in 2019 had LER >1: 2 rows of maize at increased density: 1 row okra at prescribed density. LER was >1 for all intercrops in NR in 2020, although the treatment with the highest LER (2.28) was the same as in 2019. (2 rows of maize at higher density: 1 row of okra at recommended density).

**Table 3.** Yields (kg/ha) and land equivalent ratios (LER) of okra and maize in the intercropped farm fields under different planting densities in the Northern Region (NR) of Ghana during 2019 and 2020 humid seasons.

| | | NR 2019 | | | NR 2020 | | |
|---|---|---|---|---|---|---|---|
| Plant density | Spatial arrangement | Okra | Maize | LER | Okra | Maize | LER |
| Maize (67,000) | PSR[1] | | 2368 | | | 2678 | |
| Maize (133,000) | PSH[2] | | 3522 | | | 2311 | |
| Okra (56,000) | PSR[1] | 2632 | | | 1289 | | |
| Okra (37,000) | PSL[3] | 2597 | | | 1339 | | |
| Maize (67,000) + Okra (56,000) | 1MR[4] : 1EPR[5] | 1214 | 898 | 0.72 | 950 | 2022 | 1.61 |
| Maize (67,000) + Okra (37,000) | 1MR[4] : 2EPL[6] | 1063 | 1079 | 0.72 | 861 | 1289 | 1.20 |
| Maize (133,000) + Okra (56,000) | 2MH[7] : 1EPR[5] | 852 | 1823 | 1.09 | 917 | 4192 | 2.28 |
| Maize (133,000) + Okra (37,000) | 2MH[7] : 2EPL[5] | 1011 | 1010 | 0.82 | 1050 | 3594 | 2.13 |
| *LSD* | | 1018.3** | 24.8** | | *NS* | *NS* | |

*$P$ < 0.05;***P* < 0.01; *NS:* ANOVA not significant with 95% confidence interval.

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Eggplant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density

Treatments with LER>1 differed by region, which can be explained by differences in annual rainfall distribution and agricultural methods. In 2020, the treatment with two

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rows of higher density okra and two rows of lower density maize was more helpful in UWR; in 2020, the spatial arrangement with one row of maize at recommended density and two rows of lower density okra was most effective in UER. Intercropping was more advantageous in the NR in 2019 and 2020 for the spatial arrangement of 2 rows of maize at greater density and 1 row of okra at recommended density. When the LER was more than one, intercropping okra and maize resulted in synergistic yield interactions between the two crops.

### *3.2. Optimized spatial arrangement x planting density for roselle-maize intercrops in three regions of Ghana*

In 2019 and 2020, the effects of treatments of spatial arrangements x planting density in UWR on roselle and maize were not significant (Table 4). Over a two-year period, the LER for all intercrops was more than one (2019 and 20120). Over two years, the LER was highest (>2) for 2 rows of maize planted at a greater density: 1 row of roselle planted at the pre-scribed density.

**Table 4.** Yields (kg/ha) and land equivalent ratios (LER) of roselle and maize in the intercropped farm fields under different planting densities in Upper West Region (UWR) of Ghana during 2019 and 2020 humid seasons.

| | | UWR 2019 | | | UWR 2020 | | |
|---|---|---|---|---|---|---|---|
| Plant density | Spatial arrangement | Roselle | Maize | LER | Roselle | Maize | LER |
| Maize (67,000) | PSR[1] | | 2275 | | | 3742 | |
| Maize (133,000) | PSH[2] | | 2548 | | | 4508 | |
| Roselle (296,000) | PSR[1] | 2667 | | | 694,4 | | |
| Roselle (99,000) | PSL[3] | 3000 | | | 1111,1 | | |
| Maize (67,000) + Roselle (296,000) | 1MR[4] : 1RSR[8] | 2738 | 1931 | 1,78 | 972,2 | 3729 | 2,23 |
| Maize (67,000) + Roselle (99,000) | 1MR[4] : 2RSL[9] | 2548 | 1128 | 1,29 | 694,4 | 2725 | 1,23 |
| Maize (133,000) + Roselle (296,000) | 2MH[7] : 1RSR[8] | 2595 | 2489 | 2,07 | 1388,9 | 2754 | 2,74 |
| Maize (133,000) + Roselle (99,000) | 2MH[7] : 2RSL[9] | 2571 | 1722 | 1,61 | 833,3 | 3225 | 1,61 |
| *LSD* | | *NS* | *NS* | | *NS* | *NS* | |

*$P < 0.05$;**$P < 0.01$; *NS:* ANOVA not significant with 95% confidence interval.

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Egg-plant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density.

Treatment effects were significant in UER for maize (p=0.019) in 2019, roselle (p=0.001) in 2020, and maize (p=0.008) in 2021. In 2019, the effects of interventions on roselle were not significant (p=0.758) (Table 5). In 2019, the treatment consisting of 1 row of maize at suggested density with 1 row of roselle at recommended density outperformed a solo crop of either crop (5803 kg/ha). Regardless of the crop involved, solitary crops outperformed intercrops in 2020. In 2019, the LER for all intercrops was 1, while in 2020, it was 1 for spatial arrangements x density of 2 rows maize at greater density: 2 rows roselle at lower density. LER ≥ 1 was observed in this treatment during the course of two years of testing (2019 and 2020).

**Table 5.** Yields (kg/ha) and land equivalent ratios (LER) of roselle and maize in the intercropped farm fields under different planting densities in Upper East Region (UER) of Ghana during 2019 and 2020 humid seasons.

| | | UER 2019 | | | UER 2020 | | |
|---|---|---|---|---|---|---|---|
| Plant density | Spatial arrangement | Roselle | Maize | LER | Roselle | Maize | LER |
| Maize (67,000) | PSR[1] | | 4797 | | | 2064 | |
| Maize (133,000) | PSH[2] | | 4487 | | | 1682 | |
| Roselle (296,000) | PSR[1] | 1319,3 | | | 2812 | | |
| Roselle (99,000) | PSL[3] | 766.0 | | | 2831 | | |
| Maize (67,000) + Roselle (296,000) | 1MR[4] : 1RSR[8] | 816.0 | 5803 | 1,55 | 1280 | 584 | 0,80 |
| Maize (67,000) + Roselle (99,000) | 1MR[4] : 2RSL[9] | 725,3 | 4487 | 1,67 | 1603 | 472 | 0,85 |
| Maize (133,000) + Roselle (296,000) | 2MH[7] : 1RSR[8] | 702,3 | 4410 | 1,45 | 1045 | 1041 | 0,88 |
| Maize (133,000) + Roselle (99,000) | 2MH[7] : 2RSL[9] | 829.3 | 6133 | 2,36 | 1588 | 910 | 1,00 |
| *LSD* | | *NS* | 1226.9* | | 657.3** | 798.6* | |

*$P < 0.05$;**$P < 0.01$; *NS:* ANOVA not significant with 95% confidence interval.

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Eggplant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density.

In NR, the impact of treatments was significant for maize and roselle in 2019, but not for these crops in 2020 (Table 6). In 2019, sole crops outperformed all intercrops. In 2019, the LER for 1 row of maize at the required density: 2 rows of roselle at lower density or 2 rows of maize at higher density: 2 rows of roselle at lower density was at least 1. In 2019, the LER for all intercrops was 2.59.

For spatial arrangement x planting density, intercropping roselle with maize consistently performed better across two years (2019 and 2020) and across all three locations, with 2 rows of maize at higher density: 2 rows of roselle at lower density. This treatment is suitable for roselle-maize intercrops in other locations.

**Table 6.** Yields (kg/ha) and land equivalent ratios (LER) of roselle and maize in the intercropped farm fields under different planting densities in Northern Region (NR) of Ghana during 2019 and 2020 humid seasons.

| | | **NR 2019** | | | NR 2020 | | |
|---|---|---|---|---|---|---|---|
| **Plant density** | **Spatial arrangement** | **Roselle** | **Maize** | LER | Roselle | Maize | LER |
| Maize (67,000) | PSR[1] | | 1958 | | | 2950,00 | |
| Maize (133,000) | PSH[2] | | 1963 | | | 2522,00 | |
| Roselle (296,000) | PSR[1] | 2812 | | | 2033 | | |
| Roselle (99,000) | PSL[3] | 2831 | | | 1689 | | |
| Maize (67,000) + Roselle (296,000) | 1MR[4] : 1RSR[8] | 1280 | 809 | 0,87 | 4239 | 2089,00 | 2,91 |
| Maize (67,000) + Roselle (99,000) | 1MR[4] : 2RSL[9] | 1603 | 1047 | 1,10 | 2939 | 2683,00 | 2,80 |
| Maize (133,000) + Roselle (296,000) | 2MH[7] : 1RSR[8] | 1045 | 826 | 0,79 | 3261 | 2911,00 | 2,59 |
| Maize (133,000) + Roselle (99,000) | 2MH[7] : 2RSL[9] | 1588 | 969 | 1,06 | 2789 | 2767,00 | 2,59 |
| | *LSD* | 657.3** | | 731.9** | *NS* | *NS* | |

*$P < 0.05$;**$P < 0.01$; *NS:* ANOVA not significant with 95% confidence interval.

[1]Pure stand @ recommended density; [2]Pure stand @ higher density; [3]Pure stand @ low density; [4]Maize @recommended density; [5]Eggplant @ recommended density; [6]Eggplant @ low density; [7]Maize @ higher density; [8]Roselle @ recommended density; [9]Roselle @ low density.

## 4. Discussion

The treatment that consisted of 2 okra rows at higher density and 2 maize rows at lower density produced the highest LER (2.12), suggesting that intercropping okra and maize at the above tested spatial arrangements and density resulted in synergistic interactions between both crops for yield. [9] found similar results in 2009 and 2010 with LER>1 in okra-maize intercrops.

With okra-maize intercrops in 2020 in the Upper East Region (UER), the effects of treatments of spatial arrangements x density were not significant for okra (p>0.052) and were significant for maize (p>0.003) (Table 2). Sole maize at the recommended density yielded higher (2,416 kg/ha) than sole maize at the higher density and all treatments of intercropped maize. The land equivalent ratio (LER) was ≥1 for treatments of 1 row of maize at recommended density: 1 row of okra at recommended density and 1 row of maize at recommended density: 2 rows of okra at lower density. For these two spatial arrangements, intercropping was more beneficial than sole cropping.

In the Northern Region (NR), the effect of spatial arrangements was significant for okra (p=0.006) and maize (p=0.001) in 2019 and not significant for okra (p=0.117) and maize (p=0.192) in 2020 (Table 3). Treatments with sole maize and sole okra always yielded higher than treatments of intercropped maize and intercropped okra, respectively. In NR, in 2019, only one treatment involving 2 rows of maize at higher density: 1 row of okra at recommended density had LER >1. In NR in 2020, although LER was >1 for all intercrops, the treatment with highest LER (2.28) was same as in 2019 (2 rows of maize at higher density: 1 row of okra at recommended density). Growing maize and okra at the above spatial arrangement and planting density was 128% more beneficial than growing a single crop of either crop species.

Treatments with >1 varied across regions, which can be explained by variations in the distribution of annual rainfall and farmers' practices. In 2020 in UWR, the treatment with 2 okra rows at higher density and 2 maize rows at lower density was more beneficial; in 2020 in UER spatial arrangement with 1 row of maize at recommended density and 2 rows of okra at lower density was most beneficial. In 2019 and 2020 in the NR, intercropping was most beneficial for the spatial arrangement of 2 rows of maize at higher density and 1 row of okra at recommended density. For the treatments where LER was >1, intercropping okra and maize resulted in synergistic interactions between both crops for yield.

[9] found positive interactions giving advantages to in okra-maize intercrops in 2009 and 2010 with LER>1. Such synergistic interaction observed above in UWR, UER and NR can be explained by factors such as reduction of damages by pests [8,19,10,11,12], erosion [14].

The effects of treatments of spatial arrangements x planting density in UWR were not significant for roselle and maize in 2019 and 2020 (Table 4). LER was >1 for all intercrops over two years (2019 and 2020). LER was highest (>2) across two years for 2 rows of maize at higher density: 1 row of roselle at the recommended density.

In UER, the effects of treatments were significant for maize (p=0.019) in 2019, roselle (p=0.001) and maize (p=0.008) in 2020. The effects of treatments were not significant for roselle in 2019 (p=0.758) (Table 5). In 2019, for maize crop, the treatment that involves 1 row of maize at recommended density: 1 row of roselle at the recommended density performed better (5803 kg/ha) than a sole crop of either crop. In 2020, sole crops performed better than intercrops regardless of the crop involved. In 2019, LER was ≥ 1 for all intercrops and ≥ 1 in 2020 for spatial arrangements x density of 2 rows of maize at higher density: 2 rows of roselle at lower density. This treatment showed LER ≥ 1 across all two years of tests (2019 and 2020).

In NR, the effects of treatments were significant in 2019 for maize and roselle and while the effects of treatments were not significant for these crops in 2020 (Table 6). Sole crops outperformed all intercrops in 2019. In 2019, LER was at least ≥1 for either 1 row of maize at the recommended density: 2 rows of roselle at lower density or 2 rows of maize at higher density: 2 rows of roselle at lower density. In 2020, LER was ≥2.59 for all intercrops.

Similarly, to other crop species, the synergistic interactions observed for roselle in UER and NR, may result from favorable (i) cohabitation conditions due to crop diversity that disrupts proliferation of diseases [19,8] and pests [10], and (ii) microenvironment resulted from reduced erosion and evaporation, higher soil moisture [14] and different rooting depth for each crop component.

Intercropping roselle with maize consistently performed better over two years (2019 and 2020 and across all three regions for spatial arrangement x planting density with 2 rows of maize at higher density: 2 rows of roselle at lower density. This specific treatment can be recommended for roselle-maize intercrops in

## 5. Conclusions

In Ghana and West Africa, mixed farming of vegetables and cereals is a common practice. Five vegetable crops (okra, African eggplant, roselle, pepper, and tomato) were intercropped with maize in Northern Ghana in 2019 or 2020, with treatments incorporating varying spatial configurations and planting density. Synergistic interactions were observed for vegetable: maize intensification, which exhibited more benefits than solitary cropping with no population density control. For more efficient crop production, the following spatial patterns and planting densities can be advised based on biological yields. For okra, the treatment of 2 okra rows at higher density and 2 maize rows at lower density is beneficial and can be recommended in UWR if the rainy season is normal; in UER, the most beneficial spatial arrangement to recommend is 1 row of maize at recommended density: 2 rows of okra at lower density if the rains are evenly distributed. Intercropping with a spatial layout of 2 rows of maize at a greater density: 1 row of okra at the recommended density was most beneficial and stable in NR, regardless of rainy season scarcity. As a result, it was suggested for NR. For roselle, the intercropping system 2 rows of maize at higher density: 2 rows of roselle at lower density was beneficial and stable over seasons; therefore, it was recommended for all three regions in Northern Ghana.

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## References

1. Baker, E.F.I. and Norman, D.W. (1975). Cropping systems in Northern Nigeria, In: Harwood, RR. (ed.). *Proceedings of the cropping systems workshop* held at the International Rice Research Institute, Loss Banos, Lagoons, Philippines 1975. March 18-20; 334-361
2. Beets, W.C. (1990). Raising and sustaining productivity of smallholder farming systems in the tropics. Alkmaar, Holland: *AgBé Publishing*

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3. Lawson, I.Y.D., Issahaku, A., Acheampong, S.K., Adams, B. and Tuffour, V. (2013). Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. Agriculture and Biology Journal of North America 4:358-363.
4. Tsubo, M., Walker, S. and Ogindo, H.O.A. (2005). Simulation model of cereal-legume intercropping systems for semi-arid regions. II. Model application. *Field Crop Research.* 93:23-33
5. Muoneke, C.O., Ogwuche, M.O. and Kalu, B.A. (2007). Effect of maize planting density on the performance of maize/soybean intercropping system in a Guinea savanna agroecosystem. *Afr. J. Agric. Res.* 2:667-677
6. Hugar, H.Y. and Palled, Y.B. (2008). Effect of Intercropped Vegetables on Maize and Associated Weeds in Maize-Vegetable Intercropping Systems. Karnataka Journal of Agric. Sci. 21:159-161.
7. Ouama, G. and Jeruto, P. (2010). Sustainable horticultural crop production through intercropping: The case of fruits and vegetable crops: A review. Agric. Biol. J. N. Am. 1:1098-1105.
8. Seran T.H. and Brintha, I. (2010). Review on Maize Based Intercropping. Journal of Agronomy. 9:135-145.
9. Ijoyah, M.O., Iorlamen, T. and Idoko G.A. (2012). Yield response of intercropped maize (Zea Mais L.) and okra (Abelmoschus esculentus (L.) Moench) to seasonal conditions at Makurdi in Nigeria. Journal of Natural Sciences Research. 2:79-86.
10. Nampala, P., Ogenga-Latigo, M.W., Kyamanywa, S., Adipala, E., Oyobo, N. and Jackai, L.E. (2002). Potential impact of intercropping on major cowpea field pests in Uganda. African Crop Science Journal. 10:335-344.
11. Gutierrez, C. (1999). Evaluation of maize-chilli intercrop for the management of Anthonomus eugenii in Nicaragua. Manejo Integrado de Plagas. 54:73-77. Portuguese
12. Pino, M., De-Los, A., Domini, M.E., Terry, E., Bertoli, M. and Espinosa, R. (1993). Maize as a protective crop for tomato in conditions of environmental stress. Cultivos Tropicales. 15:60-63 (Portuguese).
13. Akunda, E.M.W. (2001). Crop yields of Sorghum and soybeans in an intercrop. The Journal of Food Technology in Africa. 6:2-4.
14. Zougmoré, R., Kambou, N.F., Ouattara, K. and Guillobez, S. (2001). Sorghum-cowpea intercropping: an effective technique against runoff and soil erosion in the Sahel (Saria, Burkina Faso). Arid Soil Research and Rehabilitation. 14: 329-342.
15. Sene, M. Gallet, C. and Doré, T. (2001). Phenolic compounds in a Sahelian sorghum (Sorghum bicolor) genotype (ce (145-166)) and associated soils. Journal of Chemical Ecology. 27:81-92.
16. Willey, R.W. (1985). Evaluation and presentation of intercropping advantages. Experimental Agriculture. 2:119-133.
17. Ajeigbe, H.A., Singh, B.B. and Oseni, T.O. (2005). Cowpea–cereal intercrop productivity in the Sudan savanna zone of Nigeria as affected by planting pattern, crop variety, and pest management. *African Crop Science Journal*. 13:269–279.
18. Tsubo, M., Ogindo, H.O. and Walker, S. (2004). Yield evaluation of maize-bean intercropping in a semi arid region of South Africa. African Crop Science. 12:351-358.
19. Trenbath, B.R. (1993). Intercropping for the management of pests and diseases. Field Crop Res. 34:381-405.