



International Journal of Plant & Soil Science
3(6): 623-643, 2014; Article no. IJPSS.2014.6.008

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Effect of Groundnut – Sesame Intercropping and Nitrogen Fertilizer on Yield, Yield Components and Infection of Root – Rot and Wilt Diseases

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Authors' contributions

Author AMAG designed the study, wrote the protocol, carried out the field experiments, follow up the growth, development and harvest of all tested crops, recorded the data of all the tested crops, and reviewed the final manuscript for agronomy part. Author REAAG carried out the pathology part and reviewed the final manuscript for pathology part. All authors read and approved the final manuscript.

Conference Proceeding Full Paper

Received 13th December 2013
Accepted 22nd February 2014
Published 19th March 2014

ABSTRACT

The interaction between cropping system and mineral nutrients (nitrogen) is an important factor affecting yield and its attributes of legumes. A two year-study was carried out at Ismailia Agricultural Experiments and Research Station, ARC, Ismailia governorate, Egypt, during 2010 and 2011 summer seasons to study the effect of intercropping sesame with groundnut and three rates of nitrogen fertilization on yield and its attributes, as well as, root – rot and wilt diseases for both crops. Intercropping pattern 3 groundnut : 1 sesame recorded higher groundnut yield and its attributes than 2:2 pattern, while, the highest sesame yield and its attributes was obtained by 2:2 pattern. Increasing nitrogen fertilization rates from 107.1 to 178.5 kg N per ha resulted in significant increment in yield and its attributes of both crops. Land equivalent ratio (LER) ranged from 1.22 to 1.44. LER Values of 2:2 pattern exceeded 3:1 pattern. The highest LER was obtained when growing sesame with groundnut in 2:2 pattern and using the highest rate of nitrogen

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Note: Full paper submitted at the First International Conference on "Food and Agriculture: New Approaches" held in the National Research Centre, Cairo, Egypt from December 2 to 4, 2013.

fertilization (178.5 kg N per ha). The relative crowding coefficient (RCC) in 2:2 was associated with relatively heavy competition rather than 3:1 pattern. The lowest aggressivity was associated with 2:2 pattern and fertilized with 142.8 kg N per ha. The highest Monetary advantage index was also associated with 2:2 pattern when received the highest rate of nitrogen fertilization (178.5 kg N per ha). The gradual increase of nitrogen fertilization rates resulted in increases the percentage of dead groundnut and sesame plants under the two intercropping patterns during the two seasons. Intercropping pattern 2:2 increased the total counts of fungi and bacteria isolated from soil than the other intercropping pattern. Increasing nitrogen fertilization rates from 107.1 to 178.5 kg N per ha increased the total fungi count, whereas, it decreased the total bacteria count.

Keywords: *Intercropping; Nitrogen fertilization; Groundnut; Sesame; Root – rot; Wilt.*

1. INTRODUCTION

Interactions between plants, nutrients and disease pathogens are very complex and not completely understood. On the most basic level, plants suffering a nutrient stress will be less vigorous and more susceptible to a variety of diseases. On the other hand, the ability of a plant to express its genetic potential for disease resistance can be affected by agricultural practices. Benefit of intercropping may be disease control. In phenomenological research comparing disease in monocrops and intercrops, primarily due to foliar fungi, intercropping reduced disease in 73% of more than 200 studies [1].

Groundnut (*Arachis hypogaea*) cultivation occurs in 108 countries around the world, which is grown in all tropical and subtropical countries, up to 40° N and S. of the equator [2]. It used as food and feed in the tropics [3]. It contains about 50% oil, 25-30% protein, 20% carbohydrate and 5% fiber and ash which make a substantial contribution to human nutrition [4]. In Egypt, there is the need to expand the scope of sesame (*Sesamum indicum*) cultivation through new reclaimed lands and an effective use of modern cropping.

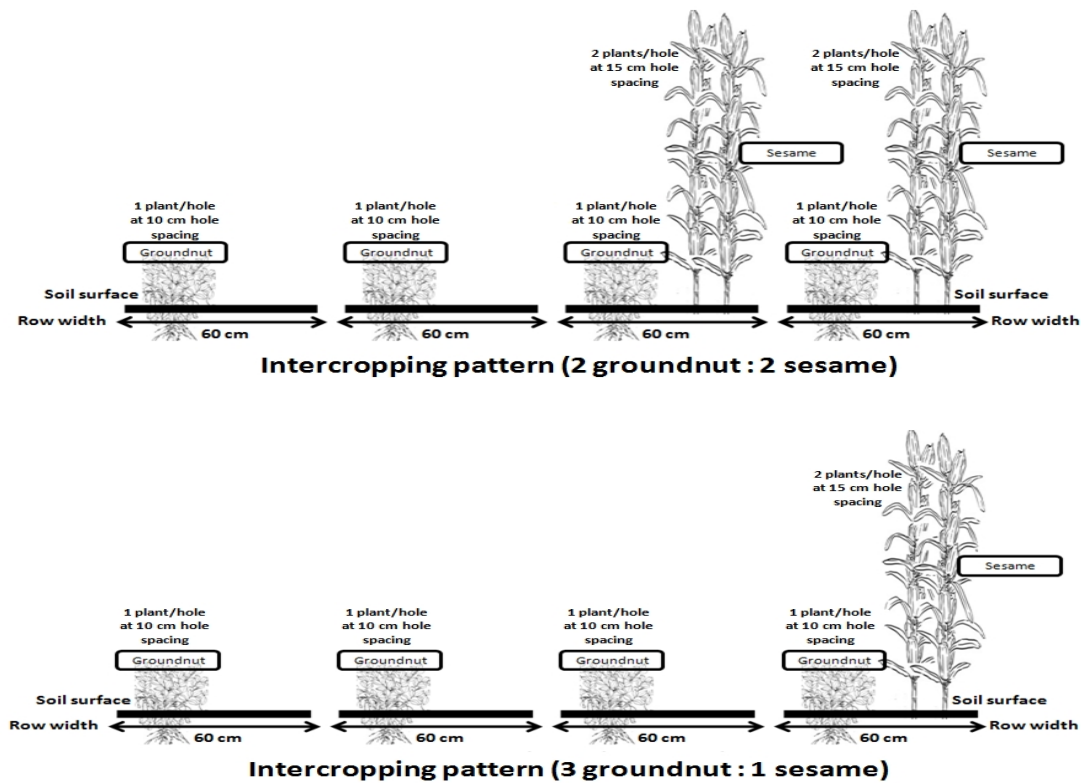
Intercropping can achieve much larger yield than sole crops by using environmental resources more fully over time or more efficiently in space [5]. Two crops differing in height, canopy, adaptation and growth habits grow simultaneously with least competition [6]. Intercropping is an important practice to increase the total yield per unit area. It is recommended to increase total agriculture products in Egypt [7]. Intercropping groundnut with sesame was most beneficial as compared to sole stand of sesame [8]. The merits of intercropping sesame with groundnut have been well documented by several investigators such as [9,10,11,12].

Legumes, like other plants, can use mineral nitrogen (ammonium and nitrate) in soil for growth, although generally do not do so as efficiently as cereals or grasses. Soil nitrate and nitrogen fixation are therefore complementary in meeting the nitrogen requirements for growth by a legume crop. Most soils and environments where plants are cultivated contain an abundance of disease pathogens. Nitrogen (N) is generally considered one of the major limiting nutrients in plant growth. Nitrogen application enhanced growth and yield characters of peanut [13]. Dose of 142.8 N/ha was adequate for producing high yield of groundnut in sandy soil [14]. Under Egyptian agricultural conditions, N is considered the most critical nutrient in crop production. The rate of N application in Egypt is one of the highest in the world [15], where the highest seed yield of groundnut was obtained by 190.4 kg N/ha [16]. High N levels increased vegetative growth of the plant, influence the microclimate in favor of

the pathogen [17]. High disease pressure increased the tissue nitrogen concentration and the total nitrogen content, but decreased the proportion of aboveground nitrogen that was partitioned to the grain [18]. Damping-off, root rot and pod rot diseases are among the most destructive diseases attacking peanut in Egypt [19]. Rhizobium soil inoculation improved shoot dry weight and nodulation status (nodules number and weight/plant), nitrogenase (N₂-ase) activity of peanut roots and enhanced microbial (bacterial and fungal) counts and dehydrogenase (DHA) enzyme activity in rhizosphere soil of peanut after 50 and 80 days from planting as compared to the untreated control [20]. The objective of this study was to study the effect of intercropping sesame with groundnut and three rates of nitrogen fertilization (107,1 142.8 and 178.5 kg N/ha) on yield and its attributes, as well as, root – rot and wilt diseases for both crops.

2. MATERIALS AND METHODS

A two year-study was carried out at Ismailia Agricultural Experiments and Research Station, A.R.C., Ismailia governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m a.s.l.), Egypt, during 2010 and 2011 summer seasons to study the effect of intercropping sesame with groundnut and three rates of nitrogen fertilization (107.1, 142.8 and 178.5 kg N/ha) on yield and its attributes, as well as, root – rot and wilt diseases for both crops because of the land has a background of high infestation with the causal of sesame and groundnut root-rot and wilt diseases. Each experiment included eight treatments of all possible combinations of two intercropping patterns and nitrogen fertilization rates. The intercropping patterns between groundnut and sesame and sole plantings of both crops are shown in Fig. 1 as follows:



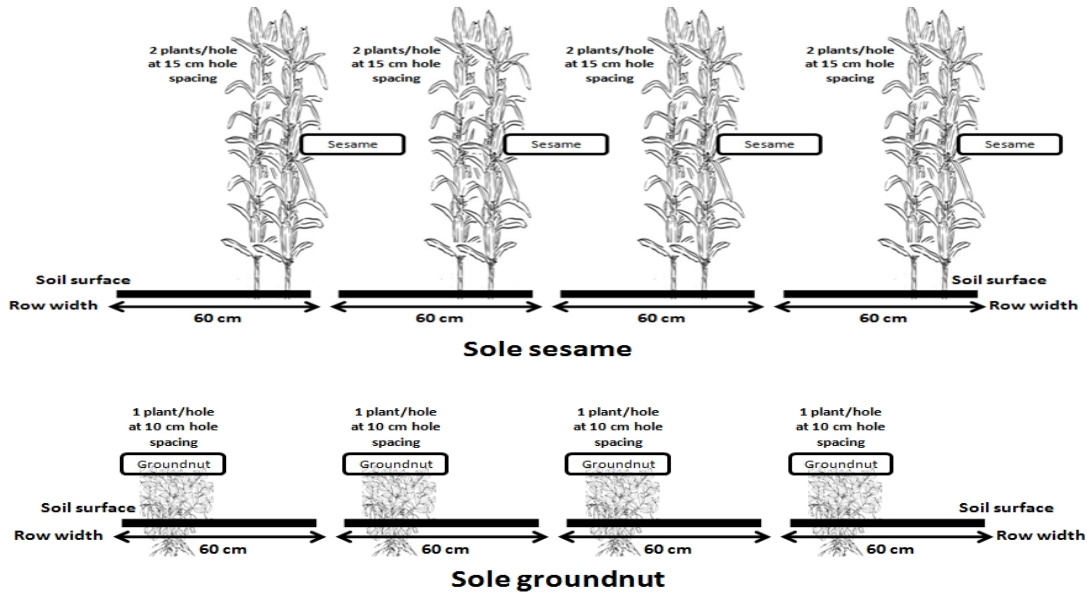


Fig. 1. Intercropping patterns of groundnut with sesame and sole plantings of both crops.

2.1 Cropping Systems

2.1.1 Intercropping patterns

2.1.1.1 Intercropping pattern 3:1

Growing groundnut on one side of all ridges with growing sesame on the other side of the fourth ridge of groundnut. This pattern resulting in 166600 plants of groundnut and 55533 sesame plants per ha (designated as 3:1 pattern).

2.1.1.2 Intercropping pattern 2:2

Growing groundnut on one side of all ridges with growing sesame on the other side of the third and fourth ridges of groundnut. This pattern resulting in 166600 plants of groundnut and 111066 sesame plants per ha (designated as 2:2 pattern).

2.1.2 Sole plantings

2.1.2.1 Sole groundnut

Recommended groundnut sole planting was conducted by leaving one plant/hole at distance 10 cm apart resulting in 166600 plants per ha. This pattern was used to estimate the competitive relationship.

2.1.2.2 Sole sesame

Recommended sesame sole planting was conducted by leaving two plants/hole at distance 15 cm apart resulting in 222133 plants per ha. This pattern was used to estimate the competitive relationship.

Sesame was seeded at 15 cm apart between holes and thinned to two plants/hole and groundnut was seeded at 10 cm apart between holes with one plant /hole after thinning. Sesame variety "Shandweel 3" and groundnut variety "Giza 6" were used in this study. Wheat was the preceding crop in both seasons. Sesame and groundnut were sown on 17th and 25th May in 2010 season and 12th and 22nd May in 2011 season, respectively. Intercropping patterns were randomly assigned to the main plots and nitrogen fertilization rates were allotted in subplots. The area of sub-plot was 14.4 m², it consisted of 8 ridges, and each ridge was 3.0 m in length and 0.6 m in width.

Table (1) shows mechanical and chemical analyses were analyzed by Soil, Water and Environment Research Institute, A.R.C., Giza, Egypt. The soil of this experiment was loamy sand. Calcium super phosphate 15.5% (P₂O₅) at the rate of 476 kg/ha was added during soil preparation. Nitrogen fertilizer was applied to groundnut and sesame in the form of ammonium nitrate (33.5%) at rate of 107.1, 142.8 and 178.5 kg/ha for intercropping patterns and at rate 71.4 and 107.1 kg/ha for sole groundnut and sole sesame, respectively, after 21 days from seeding at three intervals (before thinning, before flowering and at flower initiation). Sprinkler irrigation (water duty = 5873 m³ per ha) was the irrigation system in the area, the amount of water irrigation per hour was 69.9 m³ per ha.

Groundnut seeds were inoculated by *Bradyrhizobium* before seeding it. Groundnut and sesame were harvested on 30th and 25th September and 22nd and 28th September in the first and second seasons, respectively.

2.2 The Studied Traits

AT harvest, the following traits were measured on ten guarded plants from each plot, while, the economic yield per ha was recorded on the basis of experimental plot area:

2.2.1 Sesame plants

Plant height (cm), numbers of branches and capsules per plant, seed index (g), seed yield per plant (g) and seed yield per ha (kg).

2.2.2 Groundnut plants

Plant height (cm), numbers of branches and pods per plant, seed index (g), shelling (%), pod yield per plant (g) and pod yield per ha (kg).

2.2.3 Competitive relationships

2.2.3.1 Land equivalent ratio (LER)

LER defined as the ratio of area needed under sole planting to one of intercropping at the same management level to produce an equivalent yield [21]. Values of LERs were estimated by using data of recommended sole plantings of both crops. LER is the main

index of intercropping advantages. It represents the land required for sole planting to produce the total in yield produced by the component crops in intercropping. The values of LER are greater than 1.00, indicates an overall biological advantage of intercropping. It is calculated as follows:

$$LER = Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb}$$

Where Y_{aa} = Pure stand yield of crop a (sesame), Y_{bb} = Pure stand yield of crop b (groundnut), Y_{ab} = Intercrop yield of crop a (sesame) and Y_{ba} = Intercrop yield of crop b (groundnut)

Table 1. Mechanical and chemical properties of experimental site at Ismailia Agricultural Experiments and Research Station in 2010 and 2011 seasons

| Properties | Growing season | |
|--|----------------|------------|
| | 2010 | 2011 |
| Mechanical analysis | | |
| Depth (cm) | 0 – 60 | 0 – 60 |
| Clay (%) | 11.28 | 11.28 |
| Silt (%) | 2.00 | 2.00 |
| Sand (%) | 86.72 | 86.72 |
| Texture | Loamy sand | Loamy sand |
| Chemical analysis | | |
| Depth (cm) | 0 – 60 | 0 – 60 |
| pH | 8.5 | 8.7 |
| E.C. (mmohs/cm) | 0.25 | 0.25 |
| CaCO ₃ (%) | 0.5 | 0.6 |
| Ca ⁺² (ml/litre) | 1.8 | 2.0 |
| Mg ⁺² (ml/litre) | 0.8 | 0.4 |
| Na ⁺ (ml/litre) | 0.7 | 0.9 |
| K ⁺ (ml/litre) | 0.08 | 0.1 |
| CO ₃ ⁻² (ml/litre) | -- | -- |
| HCO ₃ ⁻ (ml/litre) | 0.7 | 0.7 |
| Cl ⁻ (ml/litre) | 0.65 | 0.75 |
| SO ₄ ⁻² (ml/litre) | 1.90 | 1.95 |
| N (ppm) | 5.0 | 5.0 |
| P (ppm) | 12.0 | 15.0 |
| K (ppm) | 52.0 | 56.0 |
| Fe (ppm) | 1.20 | 1.00 |
| Cu (ppm) | 0.02 | 0.02 |
| Zn (ppm) | 0.36 | 0.10 |
| Mn (ppm) | 1.68 | 1.16 |

2.2.3.2 Relative crowding coefficient (RCC)

RCC estimates the relative dominance of one species over the other in the intercropping system [22]. It is calculated as follows:

$$K = K_a \times K_b$$

$$K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab}]$$

$$K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba}]$$

Where Y_{aa} = Pure stand yield of crop a (sesame), Y_{bb} = Pure stand yield of crop b (groundnut), Y_{ab} = Intercrop yield of crop a (sesame), Y_{ba} = Intercrop yield of crop b (groundnut), Z_{ab} = The respective proportion of crop a in the intercropping system (sesame) and Z_{ba} = The respective proportion of crop b in the intercropping system (groundnut)

2.2.3.3 Aggressivity (Agg)

Agg represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system [23].

$$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] - [Y_{ba} / (Y_{bb} \times Z_{ba})] \quad A_{ba} = [Y_{ba} / (Y_{bb} \times Z_{ba})] - [Y_{ab} / (Y_{aa} \times Z_{ab})]$$

Where Y_{aa} = Pure stand yield of crop a (sesame), Y_{bb} = Pure stand yield of crop b (groundnut), Y_{ab} = Intercrop yield of crop a (sesame), Y_{ba} = Intercrop yield of crop b (groundnut), Z_{ab} = The respective proportion of crop a in the intercropping system (sesame) and Z_{ba} = The respective proportion of crop b in the intercropping system (groundnut).

2.2.4 Economic return

The market price of the two seasons for sesame and groundnut were 0.80 and 0.82 EUR per kg and 0.67 and 0.70 EUR per kg, respectively, in the two seasons.

Monetary advantage index (MAI) suggests that the economic assessment should be in terms of the value of land saved; this could probably be most assessed on the basis of the rentable value of this land. MAI was calculated according to the formula, suggested by [24].

$$MAI = [\text{Value of combined intercrops} \times (\text{LER}-1)]/\text{LER}$$

2.3 Isolation and count of colonies of the isolated microorganisms

One gram of soil under groundnut and sesame plants were sampled from each plot at the end of experiment and suspended with 100 ml. sterile watered in 300 ml. capped bottles. One ml of each suspension was transferred into other 100 ml. sterile water to make 1/10000 dilution for isolating fungi and then 1 ml. from the latter suspension was transferred into another 100 ml. sterile water to make 1/1000000 dilution for bacterial isolation. 1 ml. from each of second (fungi isolation) and third dilution (bacterial isolation) was flatted on surface of 9 cm in diameter PDA plates. Plates were inverted one day after plating, and incubated at $25^{\circ}\pm 2^{\circ}\text{C}$ for 5 days, while, the grown fungi and bacteria colonies were counted and tabulated. Both groundnut and sesame were carefully examined and the percentages of dead plants resulted from root-rot and wilt diseases were recorded as follows:

$$\% \text{ Dead plants} = A - B/A \times 100$$

Where A = Number of dead plants of the control and B = Number of dead plants of the treatment.

2.4 Statistical Analysis

The data for each experiment were then analyzed by M-STAT software for comparison of the mean values and the two seasons by L.S.D. test at 5% level. Response equations were calculated according to [25].

3. RESULTS AND DISCUSSION

3.1 Sesame Yield and Its Attributes

3.1.1 Intercropping patterns

Data in Tables (2, 3 and 4) indicate that intercropping patterns had significant effect on plant height and seed yield per ha, while, numbers of branches and capsules per plant, seed index and seed yield per plant were not affected in 2010 and 2011 seasons. Groundnut and sesame orientated in the alternative pattern 2:2 resulted in increase increment in plant height and seed yield per ha as compared with arranging both components in 3:1 pattern. The advantage of this pattern (2:2) in plant height and seed yield per ha over 3:1 pattern may be due to spatial arrangement of 2:2 pattern which had the highest number of sesame plants per unit area (50% of recommended sole planting), while, it was about 25% of recommended sole planting under 3:1 pattern. It is important that the unit land area, not the individual plant, produces its maximum yield. These data indicated that intercropping pattern played an important role in number of sesame plants per unit area.

Table 2. Effect of intercropping patterns, nitrogen fertilization and their interactions on sesame yield attributes in 2010 season

| Traits Treatments | Plant height (cm) | Number of branches /plant | Number of capsules /plant | Seed index (g) | Seed yield/plant (g) |
|-------------------------------|-------------------|---------------------------|---------------------------|----------------|----------------------|
| Intercropping pattern | | | | | |
| I ₁ | 72.67 | 0.122 | 24.49 | 4.19 | 13.65 |
| I ₂ | 77.22 | 0.311 | 27.43 | 4.43 | 14.96 |
| LSD .05 | 2.97 | 0.82 | 2.75 | 2.28 | 1.93 |
| Sole planting | | | | | |
| | 90.03 | 0.07 | 36.40 | 5.96 | 11.44 |
| N. fertilization rates | | | | | |
| F ₁ | 67.88 | 0.07 | 23.10 | 3.66 | 13.46 |
| F ₂ | 74.42 | 0.10 | 25.90 | 4.29 | 14.30 |
| F ₃ | 82.53 | 0.48 | 28.88 | 4.99 | 15.14 |
| LSD .05 | 1.27 | 0.62 | 1.19 | 0.51 | 0.35 |
| Interaction | | | | | |
| I ₁ F ₁ | 64.73 | 0.06 | 21.60 | 3.57 | 12.83 |
| I ₂ F ₁ | 72.50 | 0.10 | 24.43 | 4.45 | 13.63 |
| I ₁ F ₂ | 80.77 | 0.20 | 27.43 | 5.28 | 14.48 |
| I ₂ F ₂ | 71.03 | 0.07 | 24.60 | 3.75 | 14.10 |
| I ₁ F ₃ | 76.33 | 0.10 | 27.37 | 4.12 | 14.97 |
| I ₂ F ₃ | 44.30 | 0.77 | 30.33 | 4.71 | 15.80 |
| LSD .05 | 1.38 | 0.88 | 1.68 | 0.71 | 0.50 |

*I₁:3 groundnut : 1 sesame (3:1), I₂: 2 groundnut : 2 sesame (2:2)
F₁: 107.1 kg N/ha, F₂: 142.8 kg N/ha, F₃: 178.5 kg N/ha*

Increasing number of sesame plants from 25 to 50% of recommended sole planting contributed mainly in a good configuration of the attributes of the sesame crop per unit area. These results are in agreement with those obtained by [26] who found that plant population had no significant effect on number of capsules per plant. Also, [27] showed that plant population had no influence on number of seeds per capsule. Moreover, [28,29] proved that increasing plant population increased seed yield (t/ha). In another study, [30] stated that an

increase in planting population markedly would increase plant height. Also, [31] found that increasing plant density of sesame increased significantly seed yield per unit area. Finally, [32] mentioned that increasing plant population density increased seed yield per ha.

3.1.2 Nitrogen fertilization

The effect of nitrogen fertilization on sesame yield and its attributes was consistent and regular and significant. The data indicate that the values of all traits increased with increasing rate of nitrogen fertilization from 107.1 to 178.5 kg per ha (Tables 2, 3 and 4).

Table 3. Effect of intercropping patterns, nitrogen fertilization and their interactions on sesame yield attributes in 2011 season

| Traits Treatments | Plant height (cm) | Number of branches /plant | Number of capsules /plant | Seed index (g) | Seed yield/plant (g) |
|-------------------------------|-------------------|---------------------------|---------------------------|----------------|----------------------|
| Intercropping pattern | | | | | |
| I ₁ | 71.58 | 0.18 | 17.36 | 3.63 | 13.21 |
| I ₂ | 86.64 | 0.64 | 22.51 | 3.91 | 15.15 |
| LSD .05 | 5.72 | 0.96 | 6.78 | 1.15 | 2.99 |
| Sole planting | | | | | |
| | 96.73 | 0.13 | 35.64 | 4.87 | 10.54 |
| N. fertilization rates | | | | | |
| F ₁ | 73.35 | 0.17 | 17.92 | 3.29 | 13.22 |
| F ₂ | 78.92 | 0.37 | 21.67 | 3.80 | 14.07 |
| F ₃ | 85.07 | 0.70 | 20.27 | 4.21 | 15.24 |
| LSD .05 | 1.29 | 0.51 | 5.61 | 0.46 | 0.97 |
| Interaction | | | | | |
| I ₁ F ₁ | 65.07 | 0.33 | 14.13 | 3.49 | 14.24 |
| I ₂ F ₁ | 71.713 | 0.53 | 17.77 | 3.84 | 15.17 |
| I ₁ F ₂ | 77.96 | 1.07 | 20.17 | 4.40 | 16.03 |
| I ₂ F ₂ | 81.63 | 0.00 | 21.70 | 3.09 | 12.20 |
| I ₁ F ₃ | 86.12 | 0.20 | 25.47 | 3.76 | 12.97 |
| I ₂ F ₃ | 92.17 | 0.33 | 20.37 | 4.03 | 14.44 |
| LSD .05 | 1.83 | 0.72 | 9.71 | 0.65 | 1.37 |

I₁:3 groundnut : 1 sesame (3:1), I₂: 2 groundnut : 2 sesame (2:2)

F₁: 107.1 kg N/ha, F₂: 142.8 kg N/ha, F₃: 178.5 kg N/ha

Increasing rate of nitrogen fertilization from 107.1 to 178.5 kg per ha increased sesame yield per ha by 10.56 percent in the first season and 16.38 percent in the second season. These data may be due to increase rate of nitrogen fertilization from 107.1 to 178.5 kg per ha enhanced root development which improved the supply of other nutrients and water to the growing parts of the plants and resulted in an increase in photosynthetic area and thereby more dry matter accumulation in different parts of sesame organs. These results are in parallel with those obtained by [33] who stated that poultry manure and nitrogen application could be attributed to increase in mineralized nutrients in manure which improved soil physical and chemical conditions and improved availability of both micro and macro nutrients, and nitrogen that were necessary for the formation of chlorophyll, efficient rooting system and production of biomass of sesame. Also, [34] demonstrated that nitrogen fertilizer application affected significantly the performance of most parameters. They added that sesame plant height was influenced significantly by nitrogen application with plant height increasing with increase in nitrogen rate, attaining a maximum height. Sesame grain

yield increased significantly with increase in the rate of nitrogen fertilization, implying that sesame yields could be boosted through an increase in nitrogen fertilizer application.

Table 4. Effect of intercropping patterns, nitrogen fertilization and their interactions on seed yield of sesame per ha in 2010 and 2011 seasons

| Traits Treatments | Seed yield/ha (kg) | |
|------------------------|--------------------|-------------|
| | 2010 season | 2011 season |
| Intercropping pattern | | |
| I_1 | 370.73 | 370.25 |
| I_2 | 442.74 | 471.78 |
| LSD .05 | 4.49 | 15.49 |
| Sole planting | 693.62 | 902.80 |
| N. fertilization rates | | |
| F_1 | 386.44 | 391.01 |
| F_2 | 406.48 | 416.97 |
| F_3 | 427.28 | 455.07 |
| LSD .05 | 10.54 | 8.09 |
| Interaction | | |
| I_1F_1 | 350.50 | 345.90 |
| I_2F_1 | 373.54 | 370.04 |
| I_1F_2 | 388.17 | 394.79 |
| I_2F_2 | 422.40 | 436.08 |
| I_1F_3 | 439.41 | 463.88 |
| I_2F_3 | 466.40 | 515.34 |
| LSD .05 | 14.89 | 11.44 |

I_1 :3 groundnut : 1 sesame (3:1), I_2 : 2 groundnut : 2 sesame (2:2)

F_1 : 107.1 kg N/ha, F_2 : 142.8 kg N/ha, F_3 : 178.5 kg N/ha

3.1.3 Interaction between intercropping patterns and nitrogen fertilization

The effect of interaction between the intercropping pattern and rates of nitrogen fertilization was significant in yield and its attributes in 2010 and 2011 seasons (Tables 2, 3 and 4). However, no regular trend predominated the treatment imposed for yield attributes traits, but, the two main variables, *i.e.* the intercropping patterns and the nitrogen fertilization rates dominated the trend of change. In general, values of the intercrop (2:2) surpassed intercropping pattern 3:1 within same rate of nitrogen fertilization. However, maximum yield per ha was obtained by growing groundnut with sesame in 2:2 pattern and using the highest rate of nitrogen fertilization (178.5 kg N/ha), whereas, intercropping groundnut with sesame in 3:1 pattern and using 107.1 kg N/ha gave the lowest yield per ha.

3.2 Groundnut Yield and Its Attributes

3.2.1 Intercropping pattern

Number of pods per plant, shelling percentage and pod yield per ha were affected significantly by shading of adjacent sesame plants, whereas, plant height, number of branches per plant, seed index and pod yield per plant were not affected in the first season, 2010 (Tables 5 and 7). However, plant height, number of pods per plant, seed index, shelling percentage and pod yield per plant were affected significantly by intercropping

groundnut with sesame, whereas, number of branches per plant and pod yield per ha were not affected in the second season, 2011 (Tables 6 and 7).

Table 5. Effect of intercropping patterns, nitrogen fertilization and their interactions on groundnut yield attributes in 2010 season

| Traits Treatments | Plant height (cm) | Number /plant | | Seed index (g) | Shelling (%) | Pod yield/plant (g) |
|-------------------------------|-------------------------|---------------|-------|-------------------|-----------------|---------------------------|
| | | branches | Pods | | | |
| Intercropping pattern | | | | | | |
| I ₁ | 45.01 | 6.41 | 26.50 | 58.67 | 0.60 | 31.12 |
| I ₂ | 47.60 | 5.57 | 23.99 | 56.22 | 0.52 | 30.29 |
| LSD .05 | 2.98 | 0.18 | 2.11 | 6.34 | 0.02 | 4.01 |
| Sole planting | 51.60 | 6.50 | 33.73 | 60.00 | 0.57 | 43.72 |
| N. fertilization rates | | | | | | |
| F ₁ | 44.43 | 5.37 | 24.50 | 54.00 | 0.52 | 27.56 |
| F ₂ | 45.85 | 6.03 | 24.22 | 56.83 | 0.55 | 30.05 |
| F ₃ | 48.64 | 6.57 | 27.02 | 61.50 | 0.61 | 34.50 |
| LSD .05 | 0.99 | 0.28 | 6.54 | 2.74 | 0.03 | 0.98 |
| Interaction | | | | | | |
| I ₁ F ₁ | 42.23 | 5.90 | 20.93 | 56.00 | 0.56 | 28.45 |
| I ₂ F ₁ | 44.57 | 6.43 | 23.57 | 58.33 | 0.60 | 30.72 |
| I ₁ F ₂ | 48.23 | 6.90 | 27.47 | 61.67 | 0.64 | 34.19 |
| I ₂ F ₂ | 46.63 | 4.83 | 28.07 | 52.00 | 0.47 | 26.68 |
| I ₁ F ₃ | 47.13 | 5.63 | 24.87 | 55.33 | 0.50 | 29.38 |
| I ₂ F ₃ | 49.04 | 6.23 | 26.57 | 61.33 | 0.58 | 34.82 |
| LSD .05 | 1.40 | 0.30 | 7.14 | 3.87 | 0.035 | 1.38 |

*I₁:3 groundnut : 1 sesame (3:1), I₂: 2 groundnut : 2 sesame (2:2)
F₁: 107.1 kg N/ha, F₂: 142.8 kg N/ha, F₃: 178.5 kg N/ha*

Intercropping pattern 3:1 had higher values for number of pods per plant, shelling percentage and pod yield per ha in 2010 Season and number of pods per plant, seed index and pod yield per plant in 2011 season in comparison with 2:2 pattern. Intercropping pattern 2:2 produced taller plants than the other intercropping pattern in the 2nd season only. Shading of adjacent sesame plants in 3:1 pattern increased pod yield per ha by 3.05 percent in the 1st season and 2.45 percent in the 2nd season as compared with 2:2 pattern. It is clear that spatial arrangement has an important influence on the degree of competition between crops [35]. Intercropping pattern 2:2 had higher plant density of sesame per unit area in comparison with 3:1 pattern which may be led to decrease in penetration of solar radiation to adjacent groundnut plants and little dry matter accumulation in the plant which reflected on decrease in pod yield per ha. It is obvious that intercropping pattern 3:1 formed favorable conditions during the early periods of groundnut growth and finally increases in pod yield per ha. These results are in harmony with those obtained by [36] who indicated that significant differences for measured parameters, in correlation with light reduction. Residual light above the peanut canopy varied from 72 to 53%. The length of main axis varied from 51.4 cm for control plot of peanut alone to 63.9 cm for peanut intercropped, with maize variety DMR-ESRW. They added that etiolation contributes to reduce the number of pods. Dry matter and seed yield dropped respectively by 55% under maize variety DMR-ESRW. The relationship between the yield reduction and the extent of shading reflected the steps of adaptation of groundnut to the lack of light stress.

Table 6. Effect of intercropping patterns, nitrogen fertilization and their interactions on groundnut yield attributes in 2011 season

| Traits Treatments | Plant height (cm) | Number /plant | | Seed index (g) | Shelling (%) | Pod yield/plant (g) |
|-------------------------------|-------------------------|---------------|-------|----------------------|-----------------|---------------------------|
| | | branches | Pods | | | |
| Intercropping pattern | | | | | | |
| I ₁ | 42.96 | 5.90 | 31.08 | 61.90 | 0.59 | 32.91 |
| I ₂ | 46.49 | 5.60 | 23.89 | 54.22 | 0.48 | 25.40 |
| LSD .05 | 2.53 | 1.49 | 4.89 | 6.58 | 0.09 | 2.77 |
| Sole planting | | | | | | |
| | 54.17 | 4.93 | 37.20 | 65.33 | 0.56 | 45.53 |
| N. fertilization rates | | | | | | |
| F ₁ | 41.32 | 5.12 | 27.38 | 54.67 | 0.49 | 25.95 |
| F ₂ | 45.00 | 5.75 | 28.85 | 57.68 | 0.54 | 28.72 |
| F ₃ | 47.70 | 6.38 | 29.22 | 61.83 | 0.58 | 32.79 |
| LSD .05 | 1.46 | 0.40 | 2.14 | 1.40 | 0.02 | 1.37 |
| Interaction | | | | | | |
| I ₁ F ₁ | 39.00 | 5.43 | 33.77 | 57.67 | 0.56 | 28.27 |
| I ₂ F ₁ | 43.13 | 5.87 | 33.77 | 61.37 | 0.59 | 32.38 |
| I ₁ F ₂ | 46.43 | 6.40 | 25.70 | 66.67 | 0.63 | 38.07 |
| I ₂ F ₂ | 43.63 | 4.80 | 21.00 | 51.67 | 0.43 | 23.63 |
| I ₁ F ₃ | 46.87 | 5.63 | 23.93 | 54.00 | 0.49 | 25.05 |
| I ₂ F ₃ | 48.97 | 6.37 | 26.73 | 57.00 | 0.53 | 27.52 |
| LSD .05 | 2.06 | 0.57 | 3.02 | 1.97 | 0.031 | 1.94 |

*I*₁:3 groundnut : 1 sesame (3:1), *I*₂: 2 groundnut : 2 sesame (2:2)
*F*₁: 107.1 kg N/ha, *F*₂: 142.8 kg N/ha, *F*₃: 178.5 kg N/ha

3.2.2 Nitrogen fertilization

Data in Tables (5, 6 and 7) indicate that there was consistent and gradual increase in groundnut yield and its attributes with increasing the rate of nitrogen fertilization from 107.1 to 178.5 kg N per ha. Differences were significant in both seasons in all traits, except number of pod per plant in the 1st season only. Increasing rate of nitrogen fertilization up to 178.5 kg N per ha led to increase in pod yield per ha by 8.87 percent in 2010 season and 11.24 percent in 2011 season. Increased nitrogen inside the plant may be helped the chlorophyll in leaves to increase and thus the groundnut yield increased as well. On the other hand, nitrogen shortage accelerated the aging process in vegetative organs such as leaves which are known as photosynthesizing organs. These results are in harmony with those obtained by [37] who found that increasing rate of nitrogen fertilization from N₁ to N₃ increased pod yield per ha.

3.2.3 Interaction between intercropping patterns and nitrogen fertilization

The interaction effect between the intercropping patterns and nitrogen fertilization on growth, yield and yield components of groundnut was significant in all traits in both seasons (Tables 5, 6 and 7), except in case of numbers of branches and pods per plant in the 1st season only. However, there was no any consistent or regular trend could be detected among the yield component traits in both seasons indicating that the interaction effect behaved apart from the main variable effect. Nevertheless it is evident that groundnut heights increased gradually with increasing the nitrogen fertilizer rate up to the highest rate (178.5 kg N/ha) whatever the intercropping pattern. Similar trend was observed for pod

yield/ha. These results are in agreement with those obtained by [18]. The data of the interaction also revealed that the maximum pod yield per ha was obtained when groundnut received the moderate rate of nitrogen and arranged in 3:1 pattern, whereas, the minimum pod yield per ha was obtained when groundnut received the same rate of nitrogen fertilization (142.8 kg N/ha) and the plants were arranged in (2:2) pattern. A very interesting result is that both maximum and minimum pod yield per ha were obtained when plant received the same rate of nitrogen indicating the paramount effect of intercropping pattern on yield of groundnut. It is evident that the higher reduction in groundnut in intercropping system as compared to groundnut sole planting may be associated with the above ground competition for light between sesame and groundnut in the mixture [24]. The intra and inter competition under intercropping conditions for light may be attributed to the extremely higher growth vigor of sesame in (2:2) pattern, which over shaded the groundnut and suppressed the yield quantity of groundnut. Intercropping generally resulted in suppressing growth of the smaller companion plants because they intercept only a small fraction of photosynthetically active radiation as a result of competition of both components for light during initiation of growth and developing. It caused an inadequate supply of assimilates to the root because of shading and thus it limited root growth, and this might affect nodule formation and further N_2 fixation.

Table 7. Effect of intercropping patterns, nitrogen fertilization and their interactions on pod yield of groundnut per ha in 2010 and 2011 seasons

| Traits Treatments | Pod yield/ha (kg) | |
|------------------------|-------------------|-------------|
| | 2010 season | 2011 season |
| Intercropping pattern | | |
| I_1 | 2532.73 | 2388.33 |
| I_2 | 2457.58 | 2331.21 |
| LSD .05 | 44.62 | 307.0 |
| Sole planting | 3063.06 | 2945.25 |
| N. fertilization rates | | |
| F_1 | 2392.43 | 2238.39 |
| F_2 | 2487.93 | 2352.63 |
| F_3 | 2604.85 | 2490.07 |
| LSD .05 | 42.84 | 71.4 |
| Interaction | | |
| I_1F_1 | 2456.16 | 2275.87 |
| I_2F_1 | 2507.92 | 2388.33 |
| I_1F_2 | 2632.87 | 2500.78 |
| I_2F_2 | 2327.64 | 2200.90 |
| I_1F_3 | 2466.87 | 2315.14 |
| I_2F_3 | 2577.54 | 2477.58 |
| LSD .05 | 58.90 | 99.9 |

I_1 : 3 groundnut : 1 sesame (3:1), I_2 : 2 groundnut : 2 sesame (2:2)
 F_1 : 107.1 kg N/ha, F_2 : 142.8 kg N/ha, F_3 : 178.5 kg N/ha

3.3 Competitive Relationships

Data on competitive relationships are presented in Table (8). Data revealed that the relative yield of groundnut (RYg) was higher than the relative yield of sesame (RYs) in both seasons under the studied intercropping patterns. While, RYg was higher in 3:1 pattern than 2:2 pattern, the reverse was true for RYs. These observations were true in both seasons and

explain the nature of competition between both components in the intercropping patterns. Data on land utilization rate indicate that all intercropping patterns gained yield advantage, since the estimated values exceeded the unit. However, LER values of 2:2 pattern exceeded 3:1 pattern in both seasons. This indicates that increasing sesame population to reach 50% of sole population did not exert heavy competition between both components. These results are coincided with those obtained by [38,39,10] who reported that the equal alternative patterns resulted in better land use efficiency, probably because of better orientation of both components in the field and/or the increase in the ratio of the second component. The relative crowding coefficient (RCC) followed the same pattern of change as the land utilization rate. However, k values of sesame were higher than k values of groundnut in both patterns and in both seasons. The results were supported by [8].

Table 8. Relative yields, land equivalent ratio (LER), aggressivity (Agg) and relative crowding coefficient (RCC) of groundnut and sesame as affected by intercropping patterns and the interaction between intercropping patterns and nitrogen fertilization in 2010 and 2011 seasons

| Traits | RY | | LER | Aggressivity | | Relative crowding coefficient | | |
|-------------------------------|-----------|--------|------|--------------|--------|-------------------------------|-----------------|------|
| | Groundnut | Sesame | | Groundnut | Sesame | K _{ab} | K _{ba} | RCC |
| 2010 season | | | | | | | | |
| I ₁ | 0.83 | 0.54 | 1.37 | - 1.31 | + 1.31 | 1.20 | 4.59 | 5.51 |
| I ₂ | 0.80 | 0.64 | 1.44 | - 0.48 | + 0.48 | 2.03 | 3.53 | 7.17 |
| I ₁ F ₁ | 0.80 | 0.51 | 1.30 | - 2.06 | + 2.06 | 1.01 | 4.09 | 4.13 |
| I ₂ F ₁ | 0.82 | 0.54 | 1.36 | - 0.77 | + 0.77 | 2.26 | 2.33 | 5.27 |
| I ₁ F ₂ | 0.81 | 0.56 | 1.37 | - 2.65 | + 2.65 | 1.07 | 5.08 | 5.44 |
| I ₂ F ₂ | 0.81 | 0.61 | 1.42 | - 0.66 | + 0.66 | 2.13 | 3.12 | 6.65 |
| I ₁ F ₃ | 0.81 | 0.63 | 1.44 | - 2.48 | + 2.48 | 1.04 | 6.92 | 7.20 |
| I ₂ F ₃ | 0.83 | 0.67 | 1.50 | - 0.94 | + 0.94 | 2.33 | 4.12 | 9.60 |
| 2011 season | | | | | | | | |
| I ₁ | 0.81 | 0.41 | 1.22 | - 0.83 | + 0.83 | 1.07 | 2.78 | 2.98 |
| I ₂ | 0.79 | 0.52 | 1.31 | - 0.26 | + 0.26 | 1.90 | 2.19 | 4.16 |
| I ₁ F ₁ | 0.77 | 0.39 | 1.16 | - 1.97 | + 1.97 | 0.85 | 2.48 | 2.11 |
| I ₂ F ₁ | 0.81 | 0.41 | 1.22 | - 0.68 | + 0.68 | 2.15 | 1.39 | 2.99 |
| I ₁ F ₂ | 0.79 | 0.44 | 1.23 | - 2.36 | + 2.36 | 0.95 | 3.11 | 2.96 |
| I ₂ F ₂ | 0.80 | 0.48 | 1.28 | - 0.86 | + 0.86 | 1.98 | 1.87 | 3.70 |
| I ₁ F ₃ | 0.79 | 0.51 | 1.30 | - 2.69 | + 2.69 | 0.92 | 4.23 | 3.89 |
| I ₂ F ₃ | 0.81 | 0.57 | 1.38 | - 1.38 | + 1.38 | 2.19 | 2.66 | 5.83 |

*I₁:3 groundnut : 1 sesame (3:1), I₂: 2 groundnut : 2 sesame (2:2)
F₁: 107.1 kg N/ha, F₂: 142.8 kg N/ha, F₃: 178.5 kg N/ha*

Data on aggressivity in Table (8) indicate that aggressivity in 3:1 pattern was associated with relatively heavy competition rather than 2:2 pattern in both seasons. However, all values were beyond the unit indicating slight competition, except in case of 3:1 pattern in the 1st season only where aggressivity exceeded the unit. However, in both patterns sesame was the dominant crop, whereas, groundnut was dominated. The data also revealed that aggressivity values were positively related to RY of groundnut and sesame. These results are coincided with those obtained by [8].

The interaction between intercropping patterns and nitrogen fertilization rates are presented in Table (8). The interaction effect was tenaciously bounded by the main variables (the

intercropping pattern and the fertilization rate). The values of RY groundnut and sesame and land utilization rate increased gradually and consistently with increasing nitrogen fertilization rate from 107.1 to 178.5 kg nitrogen per ha. These values were also greater when groundnut was oriented in 2:2 pattern. As a consequence highest land utilization rate was obtained when the equal alternative pattern 2:2 was fertilized by using the highest rate of nitrogen fertilization (178.5 kg N/ha), whereas, the lowest LER values were associated when 3:1 pattern was fertilized by using the lowest rate of nitrogen fertilization (107.1 kg N/ha). These observations were valid in both seasons.

The relative crowding coefficient followed the same trend of change as LER values. However, it is noteworthy mentioning that *k* values of sesame were always higher than those of groundnut. High aggressivity values were obtained when growing groundnut and sesame in 3:1 pattern and using the moderate rate of nitrogen fertilization (142.8 kg N/ha) in the 1st season and associated with heavy competitive pressure in the 2nd season. Whereas, the lowest aggressivity values were found when (2:2) pattern was fertilized with 142.8 kg N per ha in the 1st season and when (2:2) pattern was fertilized with 107.1 kg N per ha. In all the interacted treatments, sesame was the dominant crop, while groundnut was the dominated.

3.4 Economic Return

The averages of monetary advantage index (MAI) values of the intercropping pattern 2:2 were higher than the other intercropping pattern (Table 9). Differences between the highest and the lowest values were 366.95 and 462.51 EUR in 2010 and 2011 seasons, respectively. On the other hand, there were gradual and consistent increases in MAI values with increasing nitrogen fertilization rates up to 178.5 kg nitrogen per ha in both seasons. The highest MAI values were obtained by growing groundnut and sesame in 2:2 pattern with using the highest rate of nitrogen fertilization. These results are true in both seasons and could be recommended.

Table 9. Monetary advantage index (MAI) of sesame and groundnut as affected by the interaction between intercropping patterns and nitrogen fertilization in 2010 and 2011 seasons

| Traits Treatments | MAI | |
|-------------------------------|-------------|-------------|
| | 2010 season | 2011 season |
| Interaction | | |
| I ₁ F ₁ | 647.69 | 361.62 |
| I ₂ F ₁ | 762.73 | 497.41 |
| I ₁ F ₂ | 815.90 | 541.44 |
| I ₂ F ₂ | 813.39 | 576.83 |
| I ₁ F ₃ | 888.03 | 641.31 |
| I ₂ F ₃ | 1014.64 | 824.13 |

*I*₁:3 groundnut : 1 sesame (3:1), *I*₂: 2 groundnut : 2 sesame (2:2)
*F*₁: 107.1 kg N/ha, *F*₂: 142.8 kg N/ha, *F*₃: 178.5 kg N/ha

3.5 Total Count of Fungi of Soil

The effect of two intercropping patterns and three nitrogen fertilization rates on dead plants percentage during 2010 and 2011 seasons are shown in Table (10). The results indicate

that 107.1 kg nitrogen per ha was the most effective fertilization rate for reducing percentage of dead plants which recorded 19.3 and 20.7% for groundnut and 13.7 and 15.0% for sesame in 2010 and 2011 seasons, respectively, under 3:1 intercropping pattern. Percentage of dead plants under 2:2 intercropping pattern were 22.0 and 24.7% for groundnut as compared with sole plantings of groundnut (26.7 and 34.3%) in the first and second seasons, respectively, and 14.3 and 17.7% for sesame as compared with sole plantings of sesame (20.7 and 25.7%) in the first and second seasons, respectively.

On the other hand, the influence of 142.8 kg N per ha was less effective in reducing the number of dead plants followed by 178.5 kg nitrogen per ha treatment under the two intercropping patterns as compared with sole plantings.

Generally, increasing rate of nitrogen fertilization increased the percentage of dead plants within the same intercropping pattern. This may be due to the increase of the total fungi count causing root-rot and wilt. These results are in the line with those obtained by [40] who found that increasing nitrogen fertilization rates increased the count of some fungi including the genera *Aspergillus*, *Fusarium*, *Penicillium*, *verticillium* and others. They added that mineral fertilization strongly affected the number of microorganisms and qualitative selection of whole communities of soil microorganisms.

Table 10. Effect of intercropping patterns and nitrogen fertilization on the infection by root – rot and wilt of groundnut and sesame in 2010 and 2011 seasons

| Intercropping patterns | Nitrogen fertilization rates | Dead groundnut plants (%) | | Dead sesame plants (%) | |
|------------------------|------------------------------|---------------------------|------|------------------------|------|
| | | 2010 | 2011 | 2010 | 2011 |
| I ₁ | F ₁ | 19.0 | 20.7 | 13.7 | 15.0 |
| | F ₂ | 20.7 | 22.3 | 16.0 | 16.3 |
| | F ₃ | 23.3 | 25.3 | 17.3 | 18.7 |
| | Mean | 21.0 | 22.8 | 15.7 | 16.7 |
| I ₂ | F ₁ | 22.0 | 24.7 | 14.3 | 17.7 |
| | F ₂ | 23.3 | 26.7 | 17.3 | 18.7 |
| | F ₃ | 25.7 | 28.0 | 18.0 | 21.0 |
| | Mean | 23.7 | 26.5 | 16.5 | 19.1 |
| Sole planting | | 26.7 | 34.3 | 20.7 | 25.7 |
| LSD .05 | | 4.5 | 4.2 | 3.3 | 3.2 |

*I*₁:3 groundnut : 1 sesame (3:1), *I*₂: 2 groundnut : 2 sesame (2:2)

*F*₁: 107.1 kg N/ha, *F*₂: 142.8 kg N/ha, *F*₃: 178.5 kg N/ha

Generally, the obtained results indicate that the dead plants percentage under 2:2 pattern exceeded those obtained by 3:1 pattern. This may be due to the increase in height of sesame plants in case of 2:2 pattern rather than 3:1 pattern which resulted in dramatic change in microclimate within and under plants, *i.e.* temperature and relative humidity. This microclimate is the incubator condition and led to increase the density of soil microorganisms in case of 2:2 pattern. These results are in harmony with those obtained with [41,42] who stated that disease incidence of cotton damping –off increased under intercropping cotton with each of wheat and faba bean as compared with cotton sole and/or intercropping with onion and garlic.

However, it is noticed an increase in the percentage of dead plants in the individual case of groundnut and sesame. The presence of other species of fungi and bacteria in intercropping

pattern may play a role in inhibition of some pathogenic fungi. The obtained data are confirmed by [43,44].

3.6 Infection by Root –Rot and Wilt of Groundnut and Sesame

The gradual increase in the amount of nitrogen fertilization resulted in high increase in the total fungi count in both patterns in both seasons (Table 11). This increase was higher in case of 2:2 intercropping pattern than the other intercropping pattern. On the other hand, opposite results were recorded in case of the total count of bacteria (Table 11).

The total counts of bacteria and fungi were, to somewhat, affected by the growing season, where the total counts of bacteria and fungi were more higher during 2010 season than that of 2011 season.

The results are in agreement with those obtained by [45,46] who studied the influence of intercropping soybean and maize on soybean damping-off disease and relevant effect on the rhizosphere microorganisms. Therefore, they found that high number of microorganisms was found in the 2:2 pattern followed by 2:1 pattern. In addition, the total counts of fungi and bacteria were higher under sole planting condition in maize than sole planting of soybean.

The interaction of intercropping patterns and nitrogen fertilization rates reveal that the minimum percentage of total fungi count, dead plants percentages of groundnut and sesame were associated with plants orientated in 3:1 pattern which received 107.1 kg N per ha, whereas, the reverse was true by intercropping groundnut with sesame in 2:2 pattern and using the highest rate of nitrogen fertilization (178.5 kg N/ha).

Table 11. Effect of intercropping patterns and nitrogen fertilization on the total count of soil fungi and bacteria under field conditions in 2010 and 2011 seasons

| Intercropping patterns | Nitrogen fertilization rates | Total fungi count | | Total bacteria count | |
|------------------------|------------------------------|-------------------|-------|----------------------|------|
| | | 2010 | 2011 | 2010 | 2011 |
| I ₁ | F ₁ | 67.0 | 59.2 | 4.9 | 4.6 |
| | F ₂ | 476.3 | 351.9 | 2.7 | 4.3 |
| | F ₃ | 651.4 | 520.4 | 2.9 | 1.4 |
| | Mean | 398.2 | 310.5 | 3.5 | 3.4 |
| I ₂ | F ₁ | 185.6 | 180.1 | 5.6 | 5.1 |
| | F ₂ | 927.4 | 632.6 | 5.4 | 4.9 |
| | F ₃ | 1135.0 | 864.1 | 3.8 | 3.6 |
| | Mean | 749.3 | 558.9 | 4.9 | 4.5 |
| Sole groundnut | 71.4 | 565.7 | 495.7 | 3.1 | 2.8 |
| Sole sesame | 107.1 | 158.5 | 156.7 | 2.8 | 2.5 |
| LSD .05 | | 25.7 | 90.9 | 2.8 | 1.6 |

I₁:3 groundnut : 1 sesame (3:1), I₂: 2 groundnut : 2 sesame (2:2)

F₁: 107.1 kg N/ha, F₂: 142.8 kg N/ha, F₃: 178.5 kg N/ha

4. CONCLUSION

The study suggested that intercropping sesame with groundnut is more profitable to farmers than groundnut sole planting. The lowest rate of nitrogen fertilization (107.1 kg N/ha) was

the most effective fertilization rate to reduce the proportion of infected plants by the diseases (root – rot and wilt) for both crops under 3:1 intercropping pattern.

ACKNOWLEDGEMENTS

The authors are grateful for Prof.Dr. Ahmed S.M. Kamel, professor of Agronomy, Crop Intensification Res. Dept., Field Crops Research Institute, Agricultural Research Center, Giza, Egypt, for his valuable assistance, encouragement throughout the progress of this study and helpful assistance in writing the manuscript. Also, our grateful for Prof.Dr. Aly M.S.A. El-Taweel, Head of Scientific and Computation Res. Section, CLDSAR, Agricultural Research Center, Giza, Egypt, for his valuable assistance in statistical analysis of this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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