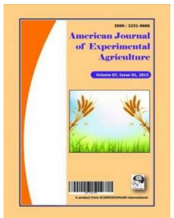

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Yield and Quality of Intercropped Wheat with Faba Bean under Different Wheat Plant Densities and Slow – Release Nitrogen Fertilizer Rates in Sandy Soil

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Authors' contributions

This work was carried out in collaboration between the authors. Author TIAW designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AMEM reviewed the experimental design and tested quality of wheat grains and faba bean seeds. Authors TIAW and AMEM managed the analyses of the study. Authors TIAW and AMEM performed the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The rapid increase of the population in Egypt together with a limited cultivated area results in an acute need for additional production of various crops. A two – year field trial was conducted in El-Boustan region, South El-Tahrir Province, El-Behira Governorate, Egypt to decrease mineral nitrogen (N) inputs of intercropped wheat and increase yield and quality of the intercrops for achieve farmer's benefit compared to sole wheat under sandy soil conditions. A split-plot design with three replications was used. Quality of wheat grains and faba bean seeds was tested in the

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laboratories of Seed Technology Research Department, Field Crops Research Institute, Agricultural Research Center. For faba bean crop, average yield of intercropped faba bean with wheat was greater by intercropping faba bean with four rows of wheat in the same ridge. Slow – release N fertilizer rates of wheat did not affect all the studied faba bean traits. Also, faba bean yield and its attributes were not affected by the interaction between wheat plant density and slow – release N fertilizer rates of wheat. Quality of faba bean seeds was not affected by wheat plant density, slow – release N fertilizer rates of wheat and the interaction between them. For wheat crop, intercropping faba bean with six rows of wheat in the same ridge had the highest grain and protein yields per ha compared to the others. All the studied wheat traits were increased by increasing N fertilizer rates of wheat from 190.4 to 285.6 kg N/ha except biological and straw yields per ha. The interaction between wheat plant density and slow – release N fertilizer rates of wheat affected significantly most of the studied wheat traits. Quality of wheat grains was not affected significantly by wheat plant density or by the interaction between wheat plant density and slow – release N fertilizer rates of wheat, meanwhile the reverse was true for slow – release N fertilizer rates of wheat. Intercropping faba bean with four rows of wheat that received 238.0 kg N/ha in form of urea slow – release N improved N uptake of wheat compared to the other treatments. Land equivalent ratio and land equivalent coefficient values for intercrops were much greater than 1.00 and 0.25, respectively, indicating less land requirements of intercropping systems than sole wheat. Farmer's benefit was achieved by intercropping faba bean with four rows of wheat that received 83.3% of the recommended mineral N fertilizer rate of wheat under sandy soil conditions.

Keywords: Intercropping; wheat plant density; faba bean; slow – release nitrogen; yield quality; nitrogen use efficiency.

1. INTRODUCTION

In Egypt, the present distribution of land use is principally the result of long-term historical processes, resulting from the interaction between socio-economic, political and environmental factors. So, the Egyptian government has advocated policies aimed at extending cultivated land and maximizing production of the existing agricultural lands since the 1980s [1] to match the high demand of food requirement with the rapid increase of the population. Now, food shortage is due to the rapid rise in the Egyptian people, limited water resources and high mineral N fertilizer costs. Currently, water is a primary limiting factor in the sector of Egyptian agriculture especially after building the Ethiopian Renaissance Dam which could be affected negatively Nile water of the country and thus a significant deficiency in the amount of water allocated for irrigation and agriculture. One possible approach to resolve this problem with regard to the high population growth would be to maximize the utilization of limited agriculture land through multiple cropping to increase productivity per unit area of available land [2]. Therefore, it is important to address our efforts to this fundamental issue by increasing crop production per unit area with reducing their water consumption especially on the reclaimed sandy soils. This can be achieved through an effective use of modern cropping and irrigation techniques with reducing the use of mineral N fertilizer for maximizing land equivalent ratio under low edaphic conditions of sandy soil. Food of the Egyptian people depends on some strategic crops such as wheat (*Triticum aestivum* L.) and faba bean (*Vicia faba* L.), especially the cultivated area of these crops in new lands reached about 261 and 16 thousand ha for wheat and faba bean, respectively, in 2013 [3]. Consequently, there is the need to minimize the food shortage gap by optimizing some agricultural practices in these soils.

It is known that beans, being legumes, are able to fix and use atmospheric N whilst wheat only uses N already in the soil. Certainly, the simultaneous growing of two or more crop species on the same piece of land by intercropping [4] is an important practice for the development of sustainable food production systems, advantages in terms of yield occur when component crop of intercropping system compete only partly for the same plant growth resources and inter-specific competition is less than intra-specific competition [5]. However, the planting pattern is an agronomic practice which may affect the interaction between the component crops of intercropping and so affects their use of environmental resources and, as a result, the success of intercropping compared with sole cropping systems. The effects of intercropping on the yield of the intercrop components can be evaluated by observing how the yield of one crop at constant seed rate alters in response to changes in seed rate of the other. In this concern, Bulson et al. [6] conducted field trails to clarify the effect of plant density on intercropped wheat and field bean and observed that there was a significant decrease in resource complementarily with increasing wheat and bean density. Hence, the sandy soil should be required proper management to offer optimum productivity of wheat and faba bean, especially intercropping cereals with legumes improves soil conservation [7], although N is considered to be the most important factor in wheat production under Egyptian agricultural conditions [8]. Accordingly, the proper system of intercropping faba bean with wheat is a fundamental tool particularly in cropping system that requires limited external inputs [9] under sandy soil conditions, especially there was a clear reduction of wheat yield up to 25 – 30% compared to sole wheat crop [10]. Particularly, intercropping system had a marked effect on environmental resource utilization in terms of more light interception, water and nutrient uptake compared to sole crop [11].

On the other hand, great efforts have been made by Egyptian scientists to improve wheat productivity and quality by increasing the efficiency of mineral N fertilizer application with controlling the release or minimizing loss of N nutrient. Mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to longer-term agroecosystem sustainability, up to societal and ecological benefits [12].The concentration of crude protein is one of the most important criteria for wheat grain quality evaluation [13].

It is known that slow-release N fertilizers are excellent alternative to soluble fertilizer. Nutrients are released at a slower rate throughout the season and the plants are able to absorption most of the nutrients without waste by leaching under sandy soil conditions. In this concern, El-Kramany [14] found that the use of slow-release N fertilizer gave the highest grain yield per plant, grain yield per unit area and grain protein content compared to the other N sources in sandy soil. Accordingly, the economic optimum rate of mineral fertilizer for each intercrop under sandy soil conditions is a crucial factor to maximize land use. Therefore, the main objective of the present research was to decrease mineral N inputs of intercropped wheat and increase yield and quality of the intercrops for achieve farmer's benefit compared to sole wheat under sandy soil conditions.

2. MATERIALS AND METHODS

A two- year study was carried out at El-Boustan region, South El-Tahrir Province, El-Behira Governorate (Lat. 30° 30' 14" N, Long. 30° 19 11" E, 21 m a.s.l.), Egypt during 2013/2014 and 2014/2015 seasons. The experimental soil had 6.70% clay, 2.02 % silt, and 71.39 % course sand, 19.89 % fine sand, and the texture was sandy. Chemical analysis of the soil (0 – 30 cm), pH value, available N, P and K were shown in Table 1. Mechanical and chemical analyses were done by Soli, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. Methods of mechanical and chemical analysis employed were as described by Chapman and Pratt [15].

Maize was the preceding summer crop in both seasons. Sprinkler irrigation was the irrigation system in this study. Irrigation for the first day (three hours/day) then skips the two successive days and so on from sowing up to harvest. Calcium super phosphate (15.5% P_2O_5) at rate of 476 kg per ha and potassium sulfate (48.0% K_2O) at rate of 119 kg per ha were applied during soil preparation in the two winter seasons. Seeds of faba bean cultivar Giza 843 were inoculated with *Rhizobium leguminosarum* and Arabic gum was used as a sticking agent. Faba bean seeds were sown on October 24th and 29th in 2013 and 2014 seasons, respectively, meanwhile grains of wheat cultivar Sakha 94 were sown on November 17th and 21st in 2013 and 2014 seasons, respectively. Mineral N fertilizer of faba bean was added at rate of 47.6 kg N/ha as urea '46.5% N" at 15 days from sowing under intercropping and sole cultures. Mineral N fertilizer of sole wheat was added at rate of 285.6 kg N/ha as urea '46.5% N' divided into three equal doses which applied at wheat sowing, 15 and 30 days from wheat sowing. Normal recommended cultural practices for growing wheat and faba bean crops were used. Faba bean plants were harvested on April 26th and 30th in 2014 and 2015, respectively. Wheat plants were harvested on May 17th and 20th in 2014 and 2015, respectively. The experiment included nine treatments which were the combination between three wheat plant densities (four, five and six rows were expressed as 67.0, 83.3 and 100 % of sole culture, respectively) with three mineral N fertilizer rates of wheat 285.6 kg N/ha as urea

Table 1. Chemical properties of the soil El – Boustan region in 2013 and 2014 seasons before growing faba bean with wheat

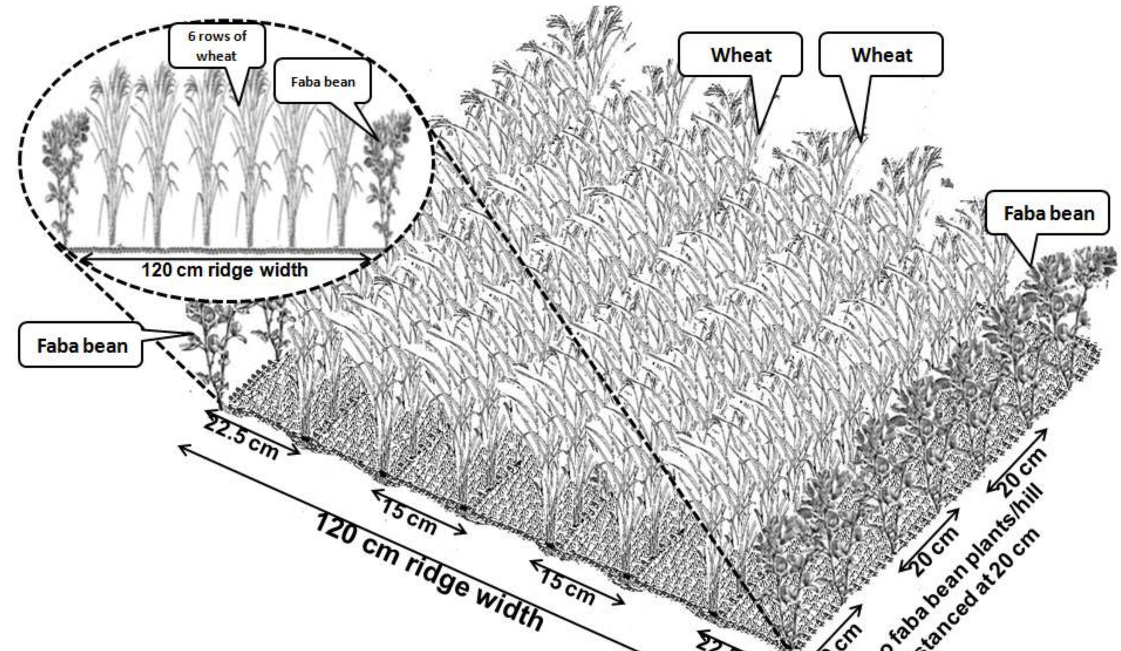
Chemical properties of the soil (0 – 30 cm)	2013 season	2014 season
pH	7.75	7.85
Available N ppm	25.00	35.00
Available P ppm	10.50	15.00
Available K ppm	90.0	110.0

'46.5% N' without urea formaldehyde form [UF_0], 238.0 kg N/ha as urea formaldehyde form [UF_1] and 190.4 kg N/ha as urea formaldehyde form [UF_2] under intercropping culture. The first mineral N fertilizer rate (285.6 kg N/ha) divided into three equal doses which applied at wheat sowing, 15 and 30 days from wheat sowing. Slow-release N fertilizer raters (238.0 and190.4 kg N/ha) were applied at wheat sowing. Slow-release N fertilizers (Enciabien 40% N) were obtained by General Organization for Agricultural Equalization Fund, ARC, Giza, Egypt. The treatments were shown in Fig. 1 as follows:

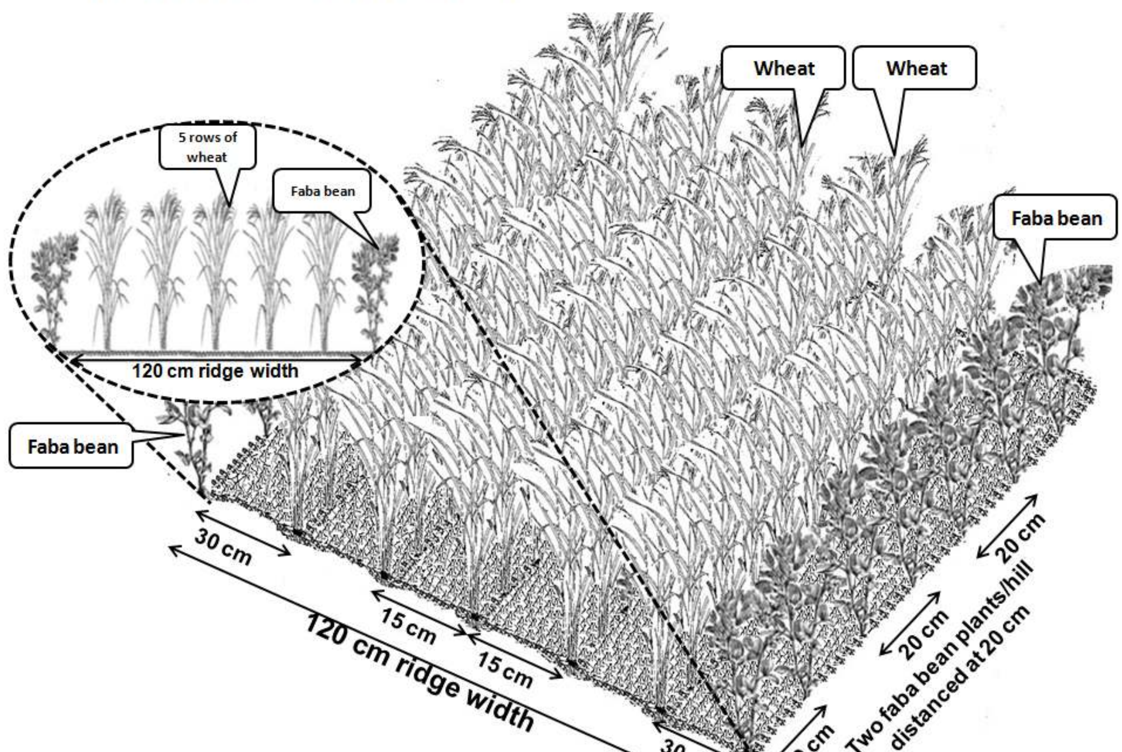
1. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile four rows of wheat were grown in middle of the ridge at 15 cm between rows that received 285.6 kg/ha (UF_0). This pattern was expressed as 50% faba bean + 67% wheat.
2. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile four rows of wheat were grown in middle of the ridge at 15 cm between rows that received 238.0 kg/ha (UF_1). This pattern was expressed as 50% faba bean + 67% wheat.
3. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile four rows of wheat were grown in middle of the ridge at 15 cm between rows that received 190.4 kg/ha (UF_2). This pattern was expressed as 50% faba bean + 67% wheat.
4. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile five rows of wheat were grown in middle of the ridge at 15 cm between rows that received 285.6 kg/ha (UF_0). This pattern was expressed as 50% faba bean + 83.3% wheat.
5. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile five rows of wheat were grown in middle of the ridge at 15 cm between rows that received 238.0 kg/ha (UF_1). This pattern was expressed as 50% faba bean + 83.3% wheat.
6. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile five rows of wheat were grown in middle of the ridge at 15 cm between rows that received 190.4 kg/ha (UF_2). This pattern was expressed as 50% faba bean + 83.3% wheat.
7. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile six rows of wheat were grown in middle of the ridge at 15 cm between rows that received 285.6 kg/ha (UF_0). This pattern was expressed as 50% faba bean + 100% wheat.
8. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile six rows of wheat were grown in middle of the ridge at 15 cm between rows that received 238.0 kg/ha (UF_1). This pattern was expressed as 50% faba bean + 100% wheat.
9. Faba bean seeds were sown in both sides of ridge (120 cm width) by growing two plants/hill distanced at 20 cm, meanwhile six rows of wheat were grown in middle of the ridge at 15 cm between rows that received 190.4 kg/ha (UF_2). This pattern was expressed as 50% faba bean + 100% wheat.

In addition to sole crops:

1. Sole wheat: pure stand of wheat ridge (60 cm width) by growing three rows distanced at 15 cm that received 285.6 kg N/ha as urea (UF_0). This pattern was used only for competitive relationships.



Intercropping faba bean with six rows of wheat (50% faba bean + 100% of wheat)



Intercropping faba bean with five rows of wheat (50% faba bean + 83.3% of wheat)

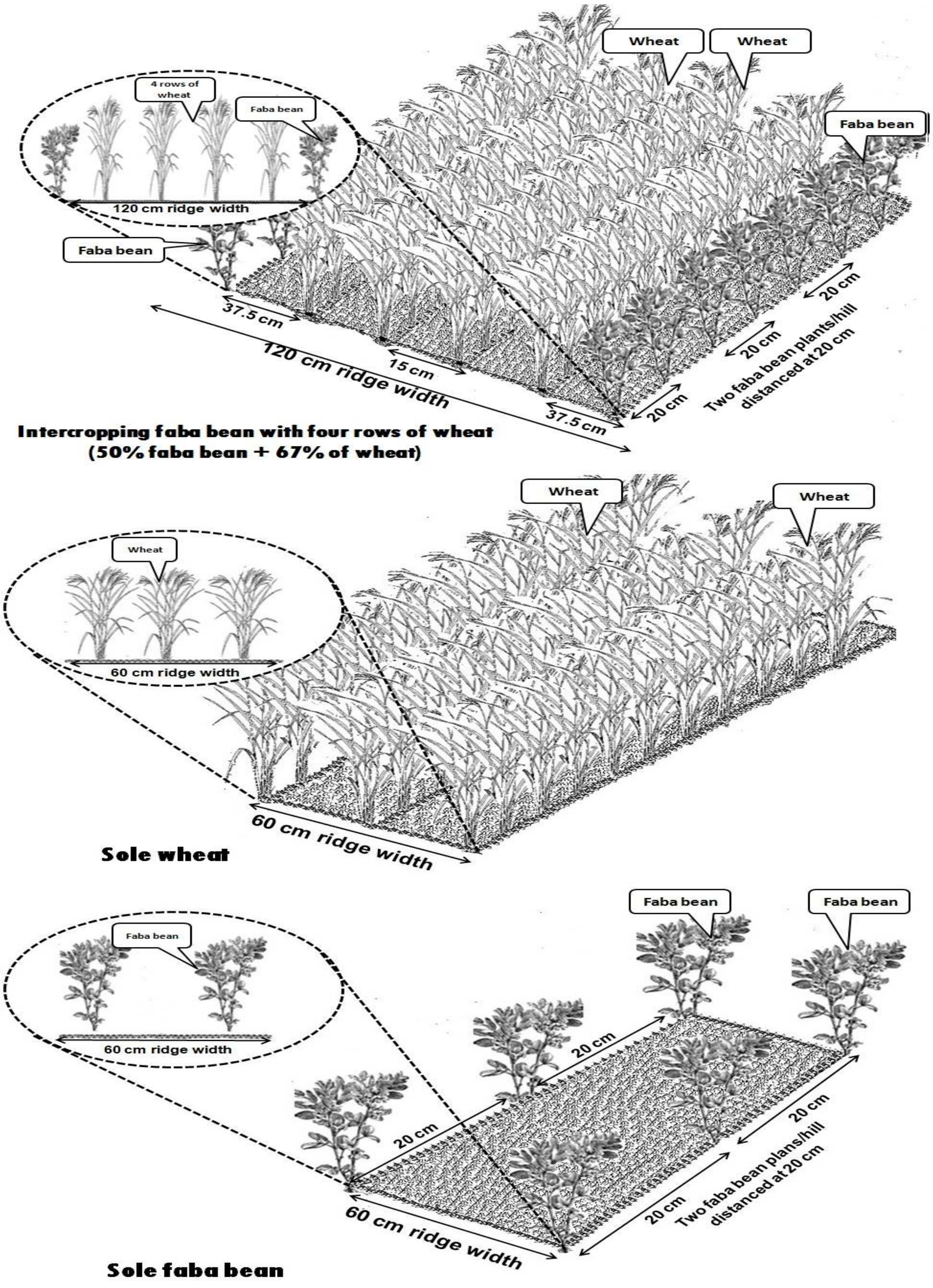


Fig. 1. Intercropping faba bean with different rows of wheat and sole culture of both crops

2. Sole faba bean: pure stand of faba bean ridge (60 cm width) by growing two rows in the ridge (two plants/hill distanced at 20 cm). This pattern was used only for competitive relationships.

A split plot design in three replications was used. Treatments of wheat plant density randomly assigned to the main plots and mineral N fertilizer rates of wheat were allocated in sub-plots. The area of sub plot was 10.8 m^2, it consisted of six ridges, and each ridge was 3.0 m in length and 0.6 m in width.

2.1 The Studied Traits

2.1.1 Faba bean seed yield and its attributes

At harvest, the following traits were measured on ten plants from each sub plot: Plant height (cm), pod yield per plant (g), seed yield per plant (g), 100 – seed weight (g). Biological and seed yields per ha (ton) were recorded on the basis of experimental plot area by harvesting all plants of each plot. Crude protein yield was calculated by seed protein content (%) x seed yield (ton per ha). Also, harvest index was estimated according to Clipson et al. [16].

2.1.2 Wheat grain yield and its attributes

At harvest, the following traits were measured on ten plants from each sub plot: Plant height (cm), spike length, number of grains per spike, 1000 – grain weight (g). Biological, straw and grain yields per ha (ton) were recorded on the basis of experimental plot area by harvesting all plants of each plot. Crude protein yield was calculated by grain protein content (%) x grain yield (ton per ha).

2.1.3 Quality of faba bean seeds and wheat grains

Samples of 50 grams from each of faba bean seeds and wheat grains were air dried, then ground and the fine powder stored in brown glass bottles. All the chemical determinations were estimated in ground seeds dried at 70^oC till constant weight. The total N of faba bean seeds and wheat grains were determined using Micro-kjeldahl apparatus according to A.O.A.C. [17]. Crude protein content was calculated by multiplying total N by 6.25 for faba bean and 5.75 for wheat [18]. Carbohydrate contents in faba bean seeds and wheat grains were analyzed according to Duis et al. [19]. These analyses were done by Seed Technology Research Department, Field Crops Research Institute, ARC.

2.1.4 Nitrogen Use Efficiency (NUE) of wheat

The N use efficiency of mineral N fertilization of wheat was calculated by this equation [20]: NUE = (Grain yield$_F$ – Grain yield$_C$) / Fertilizer N applied kg/kg, where F-fertilized wheat (the application of UF_0 or UF_1) and C-unfertilized control (the application of UF_2).

2.1.5 Competitive relationships

2.1.5.1 Land Equivalent Ratio (LER)

LER defines as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield [21]. It is calculated as follows: LER = (Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb}), Where Y_{aa} = Pure stand yield of crop a (wheat), Y_{bb} = Pure stand yield of crop b (faba bean), Y_{ab} = Intercrop yield of crop a (wheat) and Y_{ba} = Intercrop yield of crop b (faba bean).

2.1.5.2 Land Equivalent Coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship [22]. It is calculated as follows: LEC = L_a x L_b, Where L_a = relative yield of crop a (wheat) and L_b = relative yield of crop b (faba bean).

2.1.6 Farmer's benefit

Farmer's benefit (US$) was calculated as a difference between total net returns from intercropping and sole crops. Wheat grains and faba bean seeds prices presented by Bulletin of Statistical Cost Production and Net Return [3] were used. Net returns were calculated by subtraction the sum of fixed costs of wheat plus variable costs of both crops according to wheat plant density and mineral N fertilizer rates.

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package [23]. Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% [24].

3. RESULTS AND DISCUSSION

3.1 Faba bean Seed Yield and Its Attributes

3.1.1 Effect of wheat plant density

Plant height, pod and seed yields per plant, 100 – seed weight, seed yield per ha, harvest index and protein yield per ha were affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile biological yield per ha was not affected (Table 2). Pods and seed yields per plant, 100 – seed weight, seed yield per ha, harvest index and protein yield per ha were increased significantly by decreasing wheat plant density from 100 to 67 % of sole wheat density without any significant differences between 100 and 83.3 % of sole wheat density for the studied traits. Conversely, plant height was increased significantly by increasing wheat plant density per unit area from 67 to 100 % of sole wheat density under sandy soil conditions.

These data may be due to intercropping faba bean with the highest wheat plant density (six rows of wheat) affected negatively the response of faba bean plant to intercept more solar radiation compared to those grown with the other wheat plant densities under sandy soil conditions. It is important to mention that number of wheat rows per unit area could be related to the proportion of solar radiation that reaches faba bean plants by the distance between the two species during growth and development of faba bean. Intercropping faba bean with four rows of wheat formed 37.5 cm between both species, while this distance was decreased gradually with increasing number of wheat rows from 4 to 6 rows (Fig. 1). Thus, intercropping faba bean with six rows of wheat (50% faba bean + 100% wheat) led to acclimation of the legume component to low light intensity under intercropping culture. This effect may be due to genetic effect of faba bean cultivar. Such responses would be translated into alteration of plant height growth rate for helping the plants to reach enough light. Accordingly, it is expected that there was more shading around faba bean plants that suffered from mutual shading compared to those grown with the other wheat plant densities. Mutual shading is known to increase the proportion of invisible radiation, which has a specific elongating effect upon plants [25]. Obviously, plant height of intercropped faba bean with the highest plant density of wheat was increased *($P \leq 0.05$)* by 9.64% than those grown with the lowest plant density of wheat. Consequently, these results reveal that shading effects of the highest wheat plant density could be formed unfavorable environmental conditions for faba bean growth and development which increased plant hormones of faba bean. So, the observed response in plant height of intercropped faba bean with high plant density of wheat (50% faba bean + 100% wheat) could be primarily attributed to an increase of internodes number and elongation of faba bean plant as a result of increasing plant hormones under sandy soil conditions.

On the other hand, decreasing wheat plant density from 100 to 67 % of sole wheat density increased pod and seed yields per plant, 100 – seed weight, seed yield per ha, harvest index and protein yield per ha. These data may be attributed to enhancing the efficiency of faba bean plant to fix atmospheric N_2 by decreasing wheat plant density per unit area from six to four rows which reflected positively on pod and seed yields per plant and harvest index. It is likely that the treatment of 50% faba bean + 67 % wheat sustained growth of new tillers development during pod-setting and seed filling compared to the other treatments. In this concern, Badran [26] concluded that intercropping faba bean with wheat gave substantial faba bean productivity (about 85% of sole faba bean) under sandy soil conditions. Accordingly, increasing number of wheat rows per unit area from four to six may generate high competition for assimilate distribution between organs of faba bean plant, and then affected negatively seed yield per plant. Also, Yahuza [27] concluded that seed yield of bean declined as wheat seed rate increased.

3.1.2 Effect of slow – release N fertilizer

All the studied traits of faba bean were not affected by slow-release N fertilizer of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 2). From self-evident, there was no relationship between slow-release N fertilizer of wheat and the studied traits of faba bean. Similar results were obtained by El-Shamy et al. [28] who reported that mineral N fertilizer rates of the cereal component had not any relationship with all the studied traits of the legume component under intercropping conditions.

Table 2. Effect of wheat plant density, slow – release N fertilizer and their interaction on faba bean seed yield and its attributes, combined data across 2013/2014 and 2014/2015 seasons

Traits	Biological yield/ha (ton)				Plant height (cm)				Pods yield/plant (g)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	3.54	3.81	3.57	3.64	79.40	79.73	79.70	79.61	19.55	19.78	19.23	19.52
50% faba bean + 83.3% wheat	4.32	4.52	4.38	4.40	75.14	75.48	76.01	75.54	20.66	21.19	20.87	20.90
50% faba bean + 67% wheat	4.81	5.01	4.77	4.86	72.66	73.16	72.03	72.61	22.82	22.34	22.18	22.44
Average	4.22	4.44	4.24	4.30	75.73	76.12	75.91	72.92	21.01	21.10	20.76	20.95
L.S.D. 0.05 Wheat plant density				N.S.				6.16				2.75
L.S.D. 0.05 Slow – release N fertilizer				N.S.				N.S.				N.S.
L.S.D. 0.05 Interaction				N.S.				N.S.				N.S.
Sole faba bean				10.11				80.11				19.36

Table 2 continued…..

Traits	Seed yield/plant (g)				100 – seed weight (g)				Seed yield/ha (ton)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	15.55	15.78	15.23	15.52	63.44	62.81	62.92	63.05	0.67	0.73	0.68	0.69
50% faba bean + 83.3% wheat	16.66	17.19	16.87	16.90	65.68	64.94	65.17	65.26	0.87	0.92	0.89	0.89
50% faba bean + 67% wheat	18.82	18.34	18.18	18.44	67.30	66.80	66.93	67.01	1.03	1.11	1.06	1.07
Average	17.01	17.10	16.76	16.95	65.47	64.85	65.00	65.10	0.85	0.92	0.87	0.88
L.S.D. 0.05 Wheat plant density				2.62				3.68				0.32
L.S.D. 0.05 Slow – release N fertilizer				N.S.				N.S.				N.S.
L.S.D. 0.05 Interaction				N.S.				N.S.				N.S.
Sole faba bean				15.36				67.12				2.37

Table 2 continued…….

Traits	Harvest index (%)				Protein yield/ha (ton)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat								
50% faba bean + 100% wheat	18.92	19.16	19.04	19.04	0.15	0.17	0.16	0.16
50% faba bean + 83.3% wheat	20.13	20.35	20.31	20.26	0.19	0.20	0.20	0.19
50% faba bean + 67% wheat	21.41	22.15	22.22	21.92	0.22	0.23	0.23	0.22
Average	20.15	20.55	20.52	20.40	0.18	0.20	0.19	0.19
L.S.D. 0.05 Wheat plant density				2.67				0.04
L.S.D. 0.05 Slow – release N fertilizer				N.S.				N.S.
L.S.D. 0.05 Interaction				N.S.				N.S.
Sole faba bean				23.44				0.54

3.1.3 Response of wheat plant density to slow – release N fertilizer

All the studied traits of faba bean were not affected by wheat plant density x slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 2). Concerning competition for N fertilizer in wheat-bean intercropping, the bean component is capable of fixing atmospheric N_2 under favorable condition [11]. From self-evident, there was no relationship between the interaction of wheat plant density with slow-release N fertilizer rates of wheat and the studied traits of faba bean. So, the biological N fixation by the bean component should be considered, but in this experiment, there was no way to determine the amount of N derived from fixation and absorption from the soil. These data show that each of these factors act independently on all the studied traits of faba bean meaning that wheat plant density responded similarly *(P> 0.05)* to slow-release N fertilizer rates of wheat for biological yield per ha, plant height, pods and seed yield per plant, 100 – seed weight, seed yield per ha, harvest index and protein yield per ha.

3.2 Quality of Faba Bean Seeds

3.2.1 Effect of wheat plant density

Quality of faba bean seeds (N, protein and carbohydrate contents) was not affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). It is important to mention that increasing wheat plant density from four to six rows per unit area had not negative effects on N, protein and carbohydrate contents of faba bean seeds. Consequently, intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) achieved the highest seed yield without any negative effects on seed quality.

3.2.2 Effect of slow – release N fertilizer

Quality of faba bean seeds (N, protein and carbohydrate contents) was not affected significantly by slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). From self-evident, there was no relationship between slow-release N fertilizer rates of wheat and quality of faba bean seeds.

3.2.3 Response of wheat plant density to slow – release N fertilizer

Quality of faba bean seeds (N, protein and carbohydrate contents) was not affected significantly by wheat plant density x slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). From self-evident, there was no relationship between the interaction of wheat plant density with slow-release N fertilizer rates of wheat and quality of faba bean seeds.

3.3 Wheat grain yield and Its Attributes

3.3.1 Effect of wheat plant density

Plant height, spike length, number of grains per spike, 1000 – grain weight, grain yield per ha and protein yield per ha were affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, biological and straw yields per ha were not affected (Table 4).

Table 3. Effect of wheat plant density, slow – release N fertilizer and their interaction on quality of faba bean seeds, combined data across 2013/2014 and 2014/2015 seasons

Traits	Seed N content (%)				Seed protein content (%)				Seed carbohydrate content (%)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	3.78	3.81	3.86	3.81	23.63	23.86	24.18	23.89	41.66	41.30	41.86	41.60
50% faba bean + 83.3% wheat	3.59	3.52	3.63	3.58	22.44	22.02	22.72	22.39	42.54	42.26	42.88	42.56
50% faba bean + 67% wheat	3.48	3.44	3.50	3.47	21.76	21.55	21.91	21.74	43.45	43.72	44.03	43.73
Average	3.61	3.59	3.66	3.62	22.61	22.47	22.93	22.67	42.55	42.42	42.92	42.63
L.S.D. 0.05 Wheat plant density				N.S.				N.S.				N.S.
L.S.D. 0.05 Slow – release N fertilizer				N.S.				N.S.				N.S.
L.S.D. 0.05 Interaction				N.S.				N.S.				N.S.
Sole faba bean				3.67				22.94				43.76

Intercropping faba bean with six rows of wheat (50% faba bean + 100% wheat) had the highest values of plant height, grain and protein yields per ha, meanwhile, growing faba bean with four rows of wheat (50% faba bean + 67% wheat) gave the highest grain spike, number of grains per spike and 1000 – grain weight. Clearly, wheat plant density per unit area is one of the major factors that determining ability of the plant to capture light energy where plant height, grain and protein yields per ha were increased *($P \leq 0.05$)* by 1.22, 8.20 and 11.11 %, respectively, as a result of increasing wheat plant density from four to six rows per unit area under sandy soil conditions. These results could be due to increasing plant density of wheat from four to six rows per unit area increased intra-specific competition between wheat plants for basic growth resources especially solar radiation, among different resources of competition, light is one of them [29]. Clearly, intercropping faba bean with six rows of wheat could be induced potential of this cultivar in employing the environmental factors especially light to produce high grain yield per ha under sandy soil conditions.

On the other hand, grain spike, number of grains per spike and 1000 – grain weight of wheat had the opposite trend with increasing wheat plant density per unit area. It seemed that the intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) could be increased number and ability of florets to set grain which caused higher number of grains per spike, grains weight per spike and 1000 – grain weight than those intercropped with the other wheat plant densities, especially grains per spike had positive direct effect on grain yield [2]. Wheat plants sown at lower density (relative to their density in a sole culture) in a mixed crop may have access to more nutrients per plant than they would in a denser sole culture [30]. Although wheat yield attributes of four rows were higher than those of six rows, however, high seed rate of wheat plants per ridge that formed six rows (100% of sole wheat plant density) compensated the reduction in number of grains per spike, grains weight per spike and 1000 – grain weight of wheat.

3.3.2 Effect of slow – release N fertilizer

Plant height, spike length, number of grains per spike, 1000 – grain weight, grain yield per ha and protein yield per ha were affected significantly by slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, biological and straw yields per ha were not affected (Table 4). Wheat plants with the application of UF_0 or UF_1 had higher values of plant height, spike length, number of grains per spike, 1000 – grain weight, grain yield per ha and protein yield per ha than those with the application of UF_2. It is expected that increasing N rates from 190.4 to 285.6 kg N/ha contributed mainly in the amount of metabolites synthesized by wheat plants. This may be attributed to the favorable effect of the recommended mineral N fertilizer rate (285.6 kg N/ha) on the metabolic processes and physiological activates of meristimatic tissues, which are responsible for cell division and elongation in addition to formation of plant organs. However, there were no significant differences between the application of UF_0 and UF_1. Beneficial effect of the application of UF_1 could be attributed to coating material regulated N release and reduced N-leaching losses that provided a constant supply of N to roots of wheat plants. Hence, wheat plants with the application of UF_0 or UF_1 had more photosynthesis assimilates which facilitated the tillering ability of the plants, resulting in greater spike population [31]. In other words, sandy soil is very low water holding capacity and high nutrient leaching losses, wheat plants with the application of urea as slow release N fertilizer maintained the N losses as volatilization or leaching. In this concern, El-Kramany [14] found that slow-release N fertilizer gave the highest 1000-grain weight and grain yield per unit area.

Several studies showed that increasing N levels increased grain yield [32] and spike numbers and grain weight [33]. Consequently, increasing fertilizer level up to 285.6 kg N/ha increased significantly growth, yield and yield components [34].

Conversely, the negative result of UF_2 applied for wheat plants could be due to N availability did not satisfy wheat requirement for growth and development, which affected negatively the plant to produce more number of grains/spike. The onset of N shortage during critical phases of the winter cereal cycle leads to low and unstable yields [35].

Table 4. Effect of wheat plant density, slow – release N fertilizer and their interaction on wheat grain yield and its attributes, combined data across 2013/2014 and 2014/2015 seasons

Traits	Biological yield/ha (ton)				Straw yield/ha (ton)				Plant height (cm)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	16.23	15.99	15.82	16.01	10.46	10.40	10.54	10.46	96.13	95.71	94.94	95.59
50% faba bean + 83.3% wheat	16.04	15.81	15.61	15.82	10.49	10.44	10.52	10.48	95.54	95.15	94.36	95.01
50% faba bean + 67% wheat	15.92	15.70	15.49	15.70	10.56	10.51	10.67	10.58	94.92	94.56	93.81	94.43
Average	16.06	15.83	15.64	15.84	10.50	10.45	10.57	10.50	95.53	95.14	94.37	95.01
L.S.D. 0.05 Wheat plant density				N.S.				N.S.				0.76
L.S.D. 0.05 Slow – release N fertilizer				N.S.				N.S.				0.52
L.S.D. 0.05 Interaction				N.S.				N.S.				0.91
Sole wheat				16.52				10.55				95.98

Table 4 continued…..

Traits	Spike length (cm)				Grains/spike (no.)				1000 – grain weight (g)			
	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average	UF_0	UF_1	UF_2	Average
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	11.21	10.97	10.49	10.89	60.87	60.29	59.02	60.06	39.11	38.87	38.62	38.86
50% faba bean + 83.3% wheat	11.44	11.18	10.71	11.11	61.49	60.88	59.64	60.67	39.19	39.08	38.77	39.01
50% faba bean + 67% wheat	11.78	11.54	11.01	11.44	62.06	61.41	60.22	61.23	39.34	39.11	38.93	39.32
Average	11.47	11.23	10.73	11.14	61.47	60.86	59.62	60.65	39.21	39.02	38.77	38.99
L.S.D. 0.05 Wheat plant density				0.39				0.98				0.25
L.S.D. 0.05 Slow – release N fertilizer				0.27				0.79				0.21
L.S.D. 0.05 Interaction				0.52				1.13				0.27
Sole wheat				11.72				62.02				39.30

Table 4 continued……..

Traits	**Grain yield/ha (ton)**				**Protein yield/ha (ton)**			
	UF_0	**UF_1**	**UF_2**	**Average**	**UF_0**	**UF_1**	**UF_2**	**Average**
Intercropping bean with wheat								
50% f.bean + 100% wheat	5.77	5.59	5.28	5.54	0.53	0.50	0.47	0.50
50% f.bean + 83.3% wheat	5.55	5.37	5.09	5.33	0.51	0.48	0.44	0.47
50% f.bean + 67% wheat	5.36	5.19	4.82	5.12	0.48	0.45	0.41	0.45
Average	5.56	5.38	5.06	5.33	0.50	0.48	0.44	0.47
L.S.D. 0.05 Wheat plant density				0.23				0.05
L.S.D. 0.05 Slow – release N fertilizer				0.19				0.04
L.S.D. 0.05 Interaction				0.26				0.05
Sole wheat				5.97				0.54

3.3.3 Response of wheat plant density to slow-release N fertilizer

Plant height, spike length, number of grains per spike, 1000 – grain weight, grain yield per ha and protein yield per ha were affected significantly by wheat plant density x slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, biological and straw yields per ha were not affected (Table 4). Intercropping faba bean with five or six rows of wheat (50% faba bean + 83.3 or 100% wheat) interacted positively with the application of UF_0 or UF_1 to give the highest values of plant height, grain and protein yields per ha compared to the other treatments under sandy soil conditions. On the other hand, the negative effect of high wheat plant density per unit area that received UF_2 on the yield attributes could be due to high intra-specific competition between wheat plants for basic growth resources especially solar radiation and soil N. N comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components such as nucleic acids and photosynthetic pigments [36]. These data reveal that there was effect *($P \leq 0.05$)* of wheat plant density x slow-release N fertilizer rates of wheat on plant height, spike length, number of grains per spike, 1000 – grain weight, grain and protein yields per ha.

3.4 Quality of Wheat Grains

3.4.1 Effect of wheat plant density

Quality of wheat grains (N, protein and carbohydrate contents) was not affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons (Table 5). N, protein and carbohydrate of wheat grains were not affected by increasing wheat plant density per unit area from 67 to 100% of sole wheat in sandy soil under intercropping conditions. These results are in accordance with those obtained by Chen and Neill [37] who found that protein content of wheat grain was not affected by row spacing or plant density of wheat per unit area.

3.4.2 Effect of slow – release N fertilizer

Quality of wheat grains (N, protein and carbohydrate contents) was not affected significantly were affected significantly by slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 5). Wheat plants with the application of UF_0 or UF_1 had higher values (*$P \leq 0.05$*) of grain N and protein contents but it decreased grain carbohydrate content as compared to those with the application of UF_2. These increases of grain N and protein contents may be due to the amount of metabolites synthesized by wheat plants as a result of increasing N rates up to 285.6 kg N/ha. It is expected that there was an improve in albumin and gluten concentrations in grain protein content, especially the albumin and gluten gradually reduced with the increase in the amount of N [38]. The accumulation of wheat protein fractions is complex, which is relative to the genetic characteristics of species and environmental conditions [39]. These results are in accordance with those obtained by Liu and Shi [40] who showed that the increase in the amount of N was conducive to the increase in grain protein content.

3.4.3 Response of wheat plant density to slow-release N fertilizer

Quality of wheat grains (N, protein and carbohydrate contents) was not affected significantly by wheat plant density x slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Table 5). These data show that each of these factors act independently on all quality traits of wheat grains meaning that wheat plant density responded similarly *(P> 0.05)* to slow-release N fertilizer rates of wheat for grain N, protein and carbohydrate contents.

3.5 Nitrogen Use Efficiency (NUE) of Wheat

3.5.1 Effect of wheat plant density

NUE is a significant importance in crop production system due to its impact on farmer economic outcomes and environmental impact. NUE values varied from 11.50 kg per kg by intercropping faba bean with five rows of wheat (83.3% of sole wheat plant density) with the highest range of 285.6 – 190.4 kg N/ha (UF_0 – UF_2) up to 18.50 kg/kg by intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) with the lowest range of 238.0 – 190.4 kg N/ha (UF_1 – UF_2). NUE was affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). Intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) increased NUE by 15.35% compared to those grown with the other plant densities of wheat. These results could be attributed to the intercropping pattern (50% faba bean + 67% wheat) decreased intra and inter-specific competition between the same and different species, respectively, for basic growth resources.

3.5.2 Effect of slow - release N fertilizer

NUE was affected significantly by slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). Wheat plants with the application of UF_1 had higher NUE than those received UF_0. These results may be due to the use of slow release N increased dry matter and grain yield of wheat plant and produced excellent results when compared to urea. The increased N uptake may be due to the better use efficiency of applied N fertilizers in form of slow – release which retarded nitrification process enabling the slow availability of applied N. Similar results were observed by Dou and Alva [41] who demonstrated that the total N uptake by seedlings was greater for the controlled release fertilizers compared to traditional urea.

3.5.3 Response of wheat plant density to slow - release N fertilizer

NUE was affected significantly by wheat plant density x slow-release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). These results show that intercropping faba bean with four rows of wheat plants (50% faba bean + 67% wheat) with the application of UF_1 had the highest NUE compared to the other treatments. These results reveal that intercropping pattern (50% faba bean + 67% wheat) furnished suitable growth resources for wheat plants and this effect was increased by the application of UF_1 which could be provided a constant supply of N to roots of wheat plants under sandy soil conditions. These data show that each of these two factors act dependently on NUE meaning that wheat plant density responded differently *(P ≤ 0.05)* to slow-release N fertilizer rates of wheat for NUE. These results are in accordance with those obtained by Li *et al.* [42] who found that intercropping system of wheat/faba bean can be more effective in increasing crop N use efficiency.

3.6 Competitive Relationships

3.6.1 Land Equivalent Ratio (LER)

3.6.1.1 Effect of wheat plant density

LER greater than one is indicator of more efficient utilization of land in intercropping system. It is due to more efficient utilization of resources in intercropping or by increased plant density [43]. LER was affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). In general, intercropping faba bean with wheat increased *(P ≤ 0.05)* LER compared to sole crops. It ranged from 1.45 by intercropping faba bean with six rows of wheat (50% faba bean + 100% wheat) with the application of UF_2 to 1.67 by intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) with the application of UF_0 with an average of 1.57.

It is clear that LER showed benefits of cereal – legume intercropping. The actual productivity was higher than expected when faba bean was intercropped with wheat [44]. As a consequence of competitive effects observed in both species, intercrops were more efficient than pure crops in using resources for growth. Intercropping faba bean with four rows of wheat had higher LER than those that intercropped with six rows of wheat as a result of decreased intra-specific competition between wheat plants for basic growth resources. These results reveal that the advantage of the highest LER by intercropping faba bean with wheat over sole crops could be due to optimum plant density of wheat and faba bean per unit area (50% faba bean + 67% wheat) gave more space for wheat plants to grow well. Decreasing plant density of intercropped wheat from 100 to 67% of sole culture could be formed suitable above and under-ground conditions for wheat growth and development. These results are in harmony with those obtained by Agegnehu *et al.* [45] who noticed that intercropping faba bean with wheat increased both total yield and land-use efficiency.

3.6.1.2 Effect of slow – release N fertilizer

LER was affected significantly by slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). Wheat plants with the application of UF_0 or UF_1 had higher LER than those with the application of UF_2. These results may be due to the application of UF_1 reached the same significance level of UF_0 because UF_1 provided a constant supply of N to wheat roots under sandy soil conditions. These results are in agreement with those observed by Mohammed [34] who found that LER was increased with increasing N fertilizer levels.

3.6.1.3 Response of wheat plant density to slow - release N fertilizer

LER was affected significantly by wheat plant density x slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). The lowest LER was obtained by intercropping faba bean with six rows of wheat with the application of UF_2, meanwhile, the highest LER was obtained by intercropping faba bean with four rows of wheat with the application of UF_0. There were yield advantages have been recorded in intercropping faba bean with wheat [46]. These data show that each of these factors act dependently on LER meaning that wheat plant density responded differently *($P \le 0.05$)* to slow – release N fertilizer rates of wheat for LER.

3.6.2 Land Equivalent Coefficient (LEC)

3.6.2.1 Effect of wheat plant density

LEC was a measure of interaction concerned with the strength of relationship. LEC is used for a two- crop mixture the minimum expected productivity coefficient (PC) is 25 percent, that is, a yield advantage was obtained if LEC value was exceeded 0.25. LEC was affected significantly by wheat plant density in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 4). Mean LEC of intercropping faba bean with wheat was exceeded 0.25 and consequently faba bean + wheat intercropping had yield advantage. The advantage of the highest LEC could be due to optimum plant density of faba bean and wheat per unit area (50% faba bean + 67% wheat) gave more space for wheat plants to grow well. These results are in harmony with those obtained by Agegnehu *et al.* [45] who noticed that intercropping faba bean with wheat increased land-use efficiency. Also, Benincasa *et al.* [47] demonstrated that the competition of wheat reduced growth of faba bean whole plant and root, thus independent of wheat plant number.

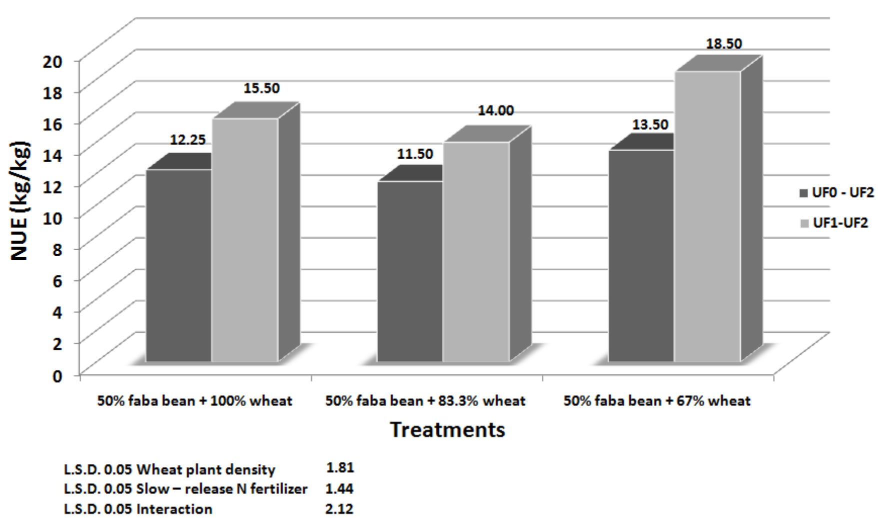
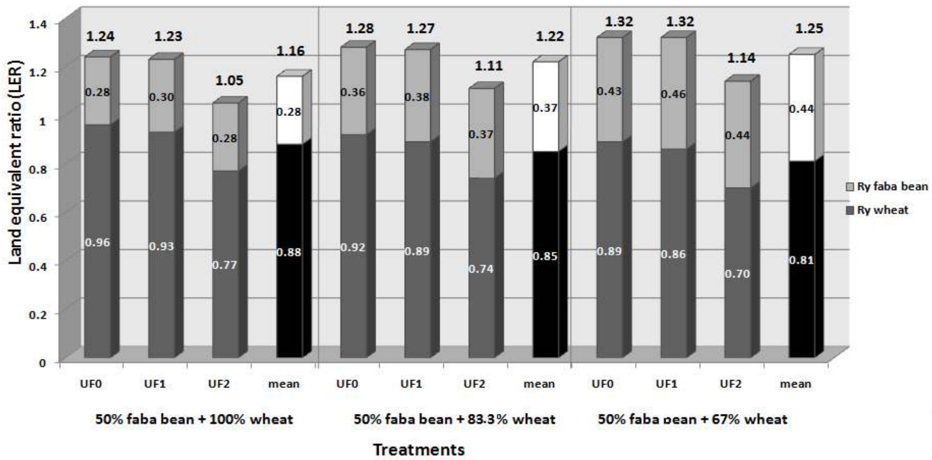


Fig. 2. Nitrogen use efficiency (NUE) affected by wheat plant density, slow – release N fertilizer and their interaction, combined data across 2013/2014 and 2014/2015 seasons

Table 5. Effect of wheat plant density, slow – release N fertilizer and their interaction on quality of wheat grains, combined data across 2013/2014 and 2014/2015 seasons

Traits	Grain N content (%)				Grain protein content (%)				Grain carbohydrate content (%)			
	UF_0	**UF_1**	**UF_2**	**Average**	**UF_0**	**UF_1**	**UF_2**	**Average**	**UF_0**	**UF_1**	**UF_2**	**Average**
Intercropping faba bean with wheat												
50% faba bean + 100% wheat	1.60	1.58	1.55	1.57	9.25	9.09	8.96	9.10	61.76	62.08	62.15	61.99
50% faba bean + 83.3% wheat	1.59	1.57	1.53	1.56	9.19	9.05	8.83	9.02	61.55	62.13	62.64	62.10
50% faba bean + 67% wheat	1.58	1.55	1.50	1.54	9.09	8.92	8.68	8.89	61.39	62.34	62.53	62.08
Average	1.59	1.56	1.52	1.55	9.17	9.02	8.82	9.00	61.56	62.18	62.44	62.06
L.S.D. 0.05 Wheat plant density				N.S.				N.S.				N.S.
L.S.D. 0.05 Slow – release N fertilizer				0.04				0.32				0.79
L.S.D. 0.05 Interaction				N.S.				N.S.				N.S.
Sole wheat				1.60				9.21				62.23



L.S.D. 0.05 Wheat plant density	0.05
L.S.D. 0.05 Slow – release N fertilizer	0.03
L.S.D. 0.05 Interaction	0.06

Fig. 3. Land equivalent ratio (LER) as affected by wheat plant density, slow – release N fertilizer and their interaction, combined data across 2013/2014 and 2014/2015 seasons

3.6.2.2 Effect of slow – release N fertilizer

LEC was affected significantly by slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 4). Wheat plants with the application of UF_0 or UF_1 had higher LEC than those with the application of UF_2. These results may be due to the application of UF_1 reached the same significance level of UF_0 because UF_1 provided a constant supply of N to roots of wheat plants under sandy soil conditions. These results are in agreement with those observed by Mohammed [34] who found that LEC was increased with increasing N fertilizer levels.

3.6.2.3 Response of wheat plant density to slow - release N fertilizer

LEC was affected significantly by wheat plant density x slow – release N fertilizer rates of wheat in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 4). The lowest LEC was obtained by intercropping faba bean with six rows of wheat (50% faba bean + 100% wheat) with the application of UF_2, meanwhile, the highest LEC was obtained by intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) with the application of UF_0. This indicates that intercropping faba bean with wheat is a competitive intercropping system by increasing wheat plant density from four to six rows. These results are in parallel with those obtained by Brandsæter and Netland [48] who indicated that legumes are weak competitors compared with cereals, and legumes are usually treated as a secondary crop. Therefore, the use of slow – release N fertilizer could be interacted with the low wheat plant density under intercropping pattern to decrease external inputs of the recommended mineral N fertilizer rate for wheat plants under sandy soil conditions. These data show that each of these factors act dependently on LEC meaning that wheat plant density responded differently *($P \le 0.05$)* to slow – release N fertilizer rates of wheat for LEC.

3.7 Farmer's Benefit

The financial returns of intercropped wheat with faba bean as compared to sole wheat are shown in Table (6). Intercropping faba bean with wheat increased total and net returns compared to sole wheat. Net returns from intercropped wheat varied between treatments from US$ 1094 to 1358/ha compared to sole wheat (542 US$/ha). Intercropping faba bean with wheat gave the highest financial value by intercropping faba bean with four rows of wheat (50% faba bean + 67% wheat) with the application of UF_1. These results indicate that growing faba bean with four rows of wheat (50% faba bean + 67% wheat) with the application of UF_1 is more profitable to farmers than sole wheat that received the recommended mineral N fertilizer (285.6 kg N/ha) for Egyptian farmers. These results are in parallel with those obtained by Munir *et al*. [49] who concluded that highest net income Rs. 10229 ha^{-1} with benefit cost ratio of 1.90 was observed in wheat grown in 100 cm spaced 4 rows of wheat and intercropping 3 rows of gram. Also, Agegnehu et al. [9] found that mixed intercropping faba bean in normal barley culture at a density not less than 37.5% of the sole faba bean gave better overall yield and income than sole culture of each crop species. Moreover, Mohammed [34] showed that intercropping faba bean with wheat that received 285.6 kg N/ha gave higher net income compared to sole wheat.

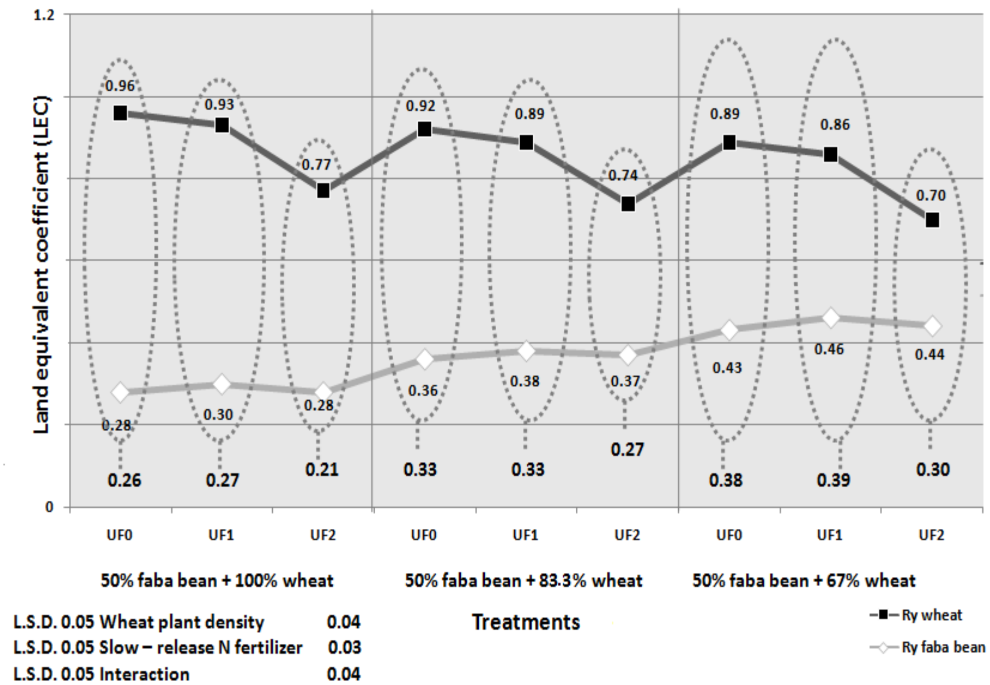


Fig. 4. Land equivalent coefficient (LEC) as affected by wheat plant density, slow – release N fertilize and their interaction, combined data across 2013/2014 and 2014/2015 seasons

Table 6. Financial return as affected by wheat plant density, slow – release N fertilizer and their interaction, combined data across 2013/2014 and 2014/2015 seasons

Traits	**Wheat**				**Faba bean**			
	UF_0	**UF_1**	**UF_2**	**Average**	**UF_0**	**UF_1**	**UF_2**	**Average**
Intercropping faba bean+wheat								
50% faba bean + 100% wheat	2256	2185	2064	2168	456	497	463	472
50% faba bean + 83.3% wheat	2170	2099	1990	2086	593	627	606	608
50% faba bean + 67% wheat	2095	2029	1884	2002	702	757	722	727
Average	2173	2104	1979	2085	583	627	597	602
Sole wheat				2334				---

Traits	**Total**				**Net**			
	UF_0	**UF_1**	**UF_2**	**Average**	**UF_0**	**UF_1**	**UF_2**	**Average**
Intercropping faba bean+wheat								
50% faba bean + 100% wheat	2712	2682	2527	2640	1199	1210	1094	1167
50% faba bean + 83.3% wheat	2763	2726	2596	2695	1264	1277	1185	1242
50% faba bean + 67% wheat	2797	2786	2606	2729	1328	1358	1216	1300
Average	2757	2731	2576	2688	1263	1281	1165	1236
Sole wheat				2334				542

Prices of main products are that of 2013: US$ 391.0 for ton of wheat; US$ 682.0 for ton of faba bean; intercropping faba bean with wheat increased variable costs of intercropping culture from US$ 625 – 758 per ha over those of sole wheat

4. CONCLUSION

Our results revealed that growing faba bean in both sides of ridge 120 cm width with growing four rows of wheat in the middle of the ridge (50% faba bean + 67% wheat) could be economically and environmentally promising in the newly reclaimed soils by using 238.0 Kg N/ha as urea form of slow – release N. This treatment decreased 16.6% of the recommended mineral N fertilizer rate of wheat plants and improved quality of wheat grains without any negative effects on quality of intercropped faba bean seeds.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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