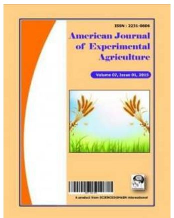

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Influences of Some Preceding Winter Crops and Nitrogen Fertilizer Rates on Yield and Quality of Intercropped Maize with Cowpea

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Authors' contributions

This work was carried out in collaboration between all authors. Author SIAW designed the study, wrote the protocol, carried out the field experiments and wrote the first draft of the manuscript. Author WMES reviewed the experimental design, wrote the results and managed the literature searches. Author AMEM tested quality of maize grains and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field study was conducted in Mallawi Agricultural Experiments and Research Station, Agricultural Research Center (ARC), El-Minia governorate, Egypt to decrease mineral nitrogen (N) inputs of maize with good yield quality and increase farmers' benefit. Local maize cultivar T.W.C. 310 was grown under intercropping and sole cultures in one row/ridge that received three mineral N fertilizer rates (75, 87.5 and 100% of the recommended N rate of maize), while local cultivar of cowpea seeds Keraim – 1 were drilled in one row and two rows/ridge under intercropping and sole cultures, respectively. A split split plot design with three replicates was used. Quality of maize grains was tested in the laboratories of Seed Technology Research Department, Field Crops Research

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Institute, ARC. Maize grain yield and its attributes were increased after harvest of legume crops compared to those grown after wheat harvest. Intercropping cowpea with maize increased grain yields per plant and per ha by 4.00 and 1.94%, respectively, in comparison with sole culture in addition to yielding 16.85 ton/ha of cowpea forage. Cowpea improved yield quality and N use efficiency (NUE) of intercropped maize after berseem cutting. 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 system than sole maize. Farmer's benefit was achieved by intercropping cowpea with maize that received 87.5% of the recommended mineral N fertilizer rate of maize after berseem cutting.

Keywords: Crop sequence; intercropping; maize; cowpea; mineral N fertilizer; yield quality.

1. INTRODUCTION

There is a strong global tendency to reduce the amount of mineral nitrogen (N) fertilization of maize (*Zea mays* L.). Some of the major causes of low maize yield are declining soil fertility and insufficient use of mineral fertilizers resulting in severe nutrient depletion of soils [1]. It is known that maize plant development is strongly dependent on the availability of N in the soil and the efficiency of N utilization for biomass production and yield [2]. It is a strategic crop and it is used for human consumption, animal and poultry feeding and industrial purposes. Demand for the maize grains in the Egyptian market is intensively increasing where maize cultivated area reached about 814435 ha in 2013 with an average yield of 7.64 ton per ha [3].

Certainly, maize provides high yield with good quality in terms of dry matter, but always there is a shortage in green forage supply during the summer season. Accordingly, intercropping a legume forage crop such as cowpea (*Vigna unguiculata* L.) with maize is very important tool for minimize the mineral N – fertilizer rates of maize in addition to cowpea could be a successful practice in cattle feeding that is severely limited by marked seasonal feed deficits in the summer season. Cowpea facilitates N uptake of the intercropping maize [4] and consequently, N symbiotic fixation has contributed to facilitate N uptake for intercropped maize [5]. Cowpea is promising double purpose forage and seed crop for its green canopy or using it in animal diets as dry seeds, as well as, it is a primary source of plant protein for humans and animals [6] in the summer season.

Quality of maize grains is primarily related to grain endosperm properties. Endosperm characteristics, although principally determined by genetics, may be influenced by the growing environment and agronomic practices, especially N fertilizer inputs [7]. The role of fertilizers, especially N is most importance in improving the yield and quality of maize [8]. It is know that endosperm accounts for approximately 85% of total grain dry weight at maturity and contains about 70% of grain protein [9].

Certainly, crop residue is a good source of nutrients in many agr – ecosystems for sustainable crop production and environment [10]. These observations led to integration of crop sequence and intercropping must be related to soil nutrient availability, especially there are strategic food crops such as wheat (*Triticum aestivum* L.), berseem (*Trifolium alexandrinum* L.) as a forage crop and faba bean (*Vicia faba*) grown during the winter season in Egypt. Therefore, the main objective of the present research was to decrease N inputs of maize crop with good yield quality and increase farmers' benefit.

2. MATERIALS AND METHODS

A research was carried out at Mallawi Agricultural Experiments and Research Station, El-Minia governorate (31°06'42" N, 30°56'45" E, 17 m a. s. l.), Egypt, during 2013/2014 and 2014/2015 seasons. Chemical analysis of the soil (0 – 30 cm) was done by General Organization for Agricultural Equalization Fund, Agricultural Research Center, Giza, Egypt (Table 1). Methods of chemical analysis employed were as described by Chapman and Pratt [11].

This experiment included eighteen treatments which were the combinations of three preceding winter crops (berseem cv. Giza 6, faba bean cv. Misr 1 and wheat cv. Beni – Sweif 1), two cropping systems (intercropped maize with cowpea and sole maize) and three mineral N fertilizer rates of maize (285.6 kg N/ha, 249.9 kg N/ha and 214.2 kg N/ha were expressed as 100, 87.5 and 75% of the recommended mineral N fertilizer rate of maize), in addition to sole culture of cowpea.

Table 1. Soil nitrogen content of the experimental soil in 2014 and 2015 seasons after harvest of the winter field crops and before growing maize and cowpea

The preceded crop	Growing season					
	2014			2015		
	N (ppm)	P (ppm)	K (ppm)	N (ppm)	P (ppm)	K (ppm)
Berseem	42.00	34.00	222.00	48.00	30.00	237.00
Faba bean	32.00	23.00	197.00	36.00	18.00	210.00
Wheat	12.00	10.00	158.00	15.00	11.50	172.00

Maize cultivar T.W.C.310 and cowpea cultivar Keraim-1 were used in this study. Water was supplied by furrow irrigation. Calcium super phosphate (15.5%P_2O_5) at rate of 357 kg/ha and potassium sulfate (48.0%K_2O) at rate of 119 kg/ha were applied during soil preparation in the two winter seasons. The previous rates were applied during soil preparation in the two summer seasons. Water was supplied by furrow irrigation. In the two winter seasons, berseem and faba bean seeds were inoculated by *Rhizobium trifolii* and *Rhizobium leguminosarum*, respectively, before seeding it and Arabic gum was used as a sticking agent. Faba bean and berseem seeds were sown on October 20th in 2013 season and October 16th in 2014 season. Wheat grains were sown on November 11th and 8th in 2013 and 2014 seasons, respectively. Wheat grains and berseem seeds were drilled at the rate of 166.6 and 59.5 kg per ha, respectively. Faba bean seeds were grown in both sides of the ridge and were distributed to two plants/hill spaced at 20 cm. Mineral N fertilizer was applied at rate of 35.7 kg N/ha for each of berseem and faba bean at 15 days from sowing. Mineral N fertilizer of wheat was applied at rate of 178.5 divided into three equal doses at sowing, 15 and 30 days from sowing. Berseem and faba bean plants were harvested on April 22nd in 2014 season and April 19th in 2015 season. Wheat plants were harvested on May 7th and 5th in 2015 season.

In the two summer seasons, cowpea seeds were sown on May 20th and 17th in 2014 and 2015 seasons, respectively, meanwhile, maize grains were sown on June 10th and 8th in 2014 and 2015 seasons, respectively. Maize was sown in one side of ridge (70 cm width) with growing one plant/hill spaced at 30 cm under intercropping and sole cultures, meanwhile, cowpea seeds were inoculated by *Rhizobium melitota* before seeding it and Arabic gum was used as a sticking agent. Cowpea seeds were grown in the other side of maize ridge (two plant/hill spaced at 20 cm) under intercropping culture. Growing cowpea in both sides of the ridge (two plant/hill spaced at 20 cm) under sole culture. In other words, the planting densities of intercropped maize with cowpea were equal to 100 and 50% of sole maize and cowpea plant densities, respectively. Mineral N fertilizer of cowpea was applied at rate of 35.7 kg N/ha at 15 days from cowpea sowing. Sole crops were used to estimate the competitive relationships. All the tested crops were grown in accordance to local agricultural practice. Cowpea plants were cutting on August 4th and 1st in 2014 and 2015 seasons, meanwhile maize plants were harvested on October 3rd and 1st in 2014 and 2015 seasons, respectively.

A split-split-plot design with three replications was used. The preceded winter field crops were randomly assigned to the main plots, cropping systems were allotted in sub plots and mineral N fertilizer rates were allotted in sub sub plots. The area of sub sub plot was 12.6 m^2, it consisted of six ridges, and each ridge was 3.0 m in length and 0.7 m in width.

2.1 The Studied Traits

2.1.1 Yield and its attributes

The following traits were measured on ten plants from each sub sub plot at harvest; plant height (cm), stem diameter (cm), number of ears/plant, ear length (cm), ear diameter (cm), ear weight (g) and grain yield per plant (g). Maize grain yield/ha (ton) and cowpea forage yield/ha (ton) were recorded on the basis of experimental plot area by harvesting all plants of each sub sub plot.

2.1.2 Quality of maize grains

Samples of 50 grams from maize grains were air dried, then ground and the fine powder stored in brown glass bottles. All the chemical determinations were estimated in ground grains dried at 70℃ till constant weight. The total N of maize grains was determined using Micro-kjeldahl apparatus according to A.O.A.C. [12]. Crude protein content of maize grains was calculated by multiplying total N by 6.25 [13]. Crude oil content of maize grains was determined using Soxhlet apparatus and N-hexane as a solvent [12]. These analyses were done by Seed Technology Research Department, Field Crops Research Institute, ARC.

2.1.3 Nitrogen Use Efficiency (NUE)

NUE for each treatment was determined using the agronomic efficiency (AE) and partial factor productivity (PFP) indices [14]: $AE = (Y - Y_o)/F$ and $PFP = (Y_o / F) + AE$, where F = amount of (fertilizer) nutrient applied (kg/ha); Y = Crop yield with applied nutrients (kg/ha) and Y_o = crop yield (kg/ha) in a control treatment with application of 214.2 kg N/ha. A basic assumption was that N uptake is the same in fertilized and unfertilized plots. This assumption was made with a caution since soil N transformations and root development may differ between fertilized and unfertilized plots [15,16].

2.1.4 Competitive relationships

2.1.4.1 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 [17]. It is calculated as follows: $LER = (Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$, where Y_{aa} = Pure stand yield of crop a (maize), Y_{bb} = Pure stand yield of crop b (cowpea), Y_{ab} = Intercrop yield of crop a (maize) and Y_{ba} = Intercrop yield of crop b (cowpea).

2.1.4.2 Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship [18]. It is calculated as follows: $LEC = L_a \times L_b$, where L_a = relative yield of crop a (maize) and L_b = relative yield of crop b (cowpea).

2.1.5 Monetary Advantage Index (MAI)

The price of maize was 309.1 US$ per ton [3], meanwhile the price of cowpea was 17.1 US$ per ton (market price). 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 Willey [19]. MAI= [Value of combined intercrops x (LER–1)]/LER.

2.2 Statistical Manipulation

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 [20]. Mean comparisons were done using least significant differences (L.S.D) method at 5 % level of probability to compare differences between the means [21].

3. RESULTS AND DISCUSSION

3.1 Yield and Its Attributes

3.1.1 Effect of the preceding crop

Ear length, diameter and weight, grain yields per plant and per ha were affected significantly by the preceding crop in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, plant height, stem diameter, number of ears per plant and forage yield of cowpea per ha were not affected (Table 2). Ear length, diameter and weight, grain yields per plant and per ha were increased significantly by the preceding legume crop (berseem or faba bean) compared to those followed by wheat. As a result of crop sequence, grain yield per plant was increased *($P \leq 0.05$)* by 18.28 and 12.40% after berseem cutting and faba bean harvest, respectively. Also, grain yield per ha was increased by 8.97 and 7.23% after berseem cutting and faba bean harvest, respectively. These results could be due to soil N, P and K contents were more available to subsequent maize plant after the preceding legumes (Table 1). Consequently, there was an increase in dry matter accumulation that reflected on ear characteristics (length, diameter and weight) during maize growth and development (Table 2), especially grain yield per plant was positively and significantly correlated with ear length [22].

Therefore, it is recommended that cereal should be grown after legumes, which would enable using the accumulated biological N for their nutrition in more rational way [23]. These results reveal that the preceding cereal crop (wheat) decreased soil nutrient availability and increased intra-specific competition between maize plants which decreased measurements of ear characteristics (length, diameter and weight) compared with the preceding legume crops. Cobs may be considered as temporary sink and the stored photosynthates were translocated to grains during their development. Accordingly, yield potential of maize plant could be affected positively or negatively by choice of the preceding winter field crop; especially grain yield per plant had positive and highly significant correlation with fresh ear weight, cob length and ear diameter [24]. So, it may be possible that there was better soil environment for the and nutrient cycling [25] as a result of a mix of living rhizobia and dead berseem or faba bean roots near the experimental soil surface. Legumes, in contrast to cereals, have a beneficial effect on grain yield of subsequent cereal crops [26].

These results are in accordance with those found by Bloem and Barnard [27] who found that maize yields after rotation with legumes were generally higher than the control treatments. They added that after the effect of N was accounted for via the N – corrected yield, it was evident that additional yield increases of 10% (average). Moreover, Ali *et al.* [28] showed that legumes as a preceding crop had increased significantly grain yield (5104 ka/ha) compared to fallow as preceding practice (3185 kg/ha). Finally, Lamlom *et al.* [29] concluded that the preceding berseem crop had positive chemical and biological effects on soil fertility that improved growth and development of maize in the following season compared to those grown after wheat harvest.

3.1.2 Effect of cropping systems

Ear length, diameter and weight, grain yields per plant and per ha and forage yield of cowpea per ha were affected significantly by cropping systems in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, plant height, stem diameter and number of ears per plant were not affected (Table 2). Ear length, diameter and weight, grain yields per plant and per ha were increased significantly by intercropping cowpea with maize in the same ridge compared to those of sole culture. As a result of intercropping, grain yields per plant and per ha were increased *($P \leq 0.05$)* by 4.00 and 1.94%, respectively, compared with sole maize. It is known that the population of plants per square meter (density) and arrangement of individual plants within a square meter determine nutrient use and grain yield of maize [30]. Although plant density was identical between mixed pattern and sole culture, however, mixed pattern increased grain yields per plant and per ha compared to sole culture. Growing cowpea with maize in the same ridge had higher grain yield per plant and per ha than those of sole culture. In this concern, Gao et al. [31] found that the grain yield of maize as an intercrop were significantly greater than those of maize as a sole crop.

These results could be attributed to maize plant benefited from biological N fixation process (BNF) by cowpea during maize growth and development. These results indicate that the fixed N of cowpea could be used by intercropped maize during growth and development. There is evidence that leguminous plants can benefit the intercrop cereals in the same season through N excretion [32] and nodule decomposition [33]. Clearly, mixed pattern played an important role to improve edaphic environmental conditions in rhizosphere of intercropped maize roots [34]. Accordingly, mixed pattern had positive effect on grain yield and its attributes of the plant (Table 2) through maximized carbon assimilation and crop productivity [35] compared to sole maize. Moreover, HamdAlla et al. [6] showed that intercropping cowpea with maize played as a reservoir for the naturally occurring biological control agents of maize plants which contributed positively in improve maize yield compared to sole maize.

With respect to cowpea yield, it was decreased by 52.45% as compared to sole cowpea (Table 2). These results could be attributed to spatial arrangement of mixed pattern increased inter-specific competition between the intercrops for basic growth resources where efficiency of C_4 crops for N and water use was higher than C_3 crops [36]. These results are in agreement with those obtained by HamdAlla et al. [6] who concluded that fresh and dry forage yields of cowpea were lower in intercropping with maize than sole cowpea.

3.1.3 Effect of mineral N fertilizer

Plant height, stem diameter, number of ears/plant, ear length, diameter and weight, grain yields per plant and per ha were affected significantly by mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, forage yield of cowpea per ha was not affected (Table 2). It is observed that plant height and stem diameter of maize plant were increased by increasing mineral N fertilizer rate from 75 to 100% of the recommended mineral N fertilizer rate. Increasing mineral N fertilizer rate from 214.2 to 285.6 kg N/ha increased plant height and stem diameter by 9.66 and 9.59%, respectively. Naturally, there was growth disadvantage of maize when maize plants received 249.9 or 214.2 kg N/ha than those received 285.6 kg N/ha. It is expected that growth and development of maize plant was affected negatively by decreasing mineral N fertilizer rate from 285.6 to 214.2 kg N/ha which reflected on growth resources such as soil N and water and converted to the lowest growth regulators and dry matter accumulation. Consequently, the increase in plant height and stem diameter might be due to the positive effect of N element on plant growth that led to progressive increase in internodes length and number during maize growth and development. It is known that plant height has been described as a measure of growth related to the efficiency in exploitation of environmental resources [37].

Also, yield attributes of maize was increased by increasing mineral N fertilizer rate from 75 to 100% of the recommended mineral N fertilizer rate. Increasing mineral N fertilizer rate from 214.2 to 285.6 kg N/ha increased number of ears/plant, ear length, diameter and weight, grain yields per plant and per ha were increased by 8.42, 3.58, 13.94, 23.90, 31.98 and 12.57%, respectively. These results could be due to 285.6 kg N/ha increased the strength of physiological source such as chlorophyll [38], effective age of leaves [39] and ear leaf N content [40] that contributed greatly in photosynthetic process during maize growth and development. These results show that the decreasing mineral N fertilizer rate from 285.6 to 214.2 kg N/ha decreased soil N availability and increased intra-specific competition between maize plants for basic growth resources especially soil N which restricted the ear characteristics (length, diameter and weight). These results are in agreement with those obtained by Bojović and Marković [41] who found that N content influenced from presence and ratio mineral elements in the soil and it was close link with chlorophyll content. Also, Hokmalipour and Darbandi [42] revealed that chlorophyll was increased significantly by increasing N fertilizer levels.

With respect to cowpea, from self-evident there was no relationship between mineral N fertilizer rates of maize and yield of cowpea. Similar results were obtained by El-Shamy et al. [43] 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.

3.1.4 Response of the preceding crop to cropping systems

Ear length, diameter and weight, grain yields per plant and per ha were affected significantly by the preceding crop x cropping systems in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, plant height, stem diameter, number of ears per plant and forage yield of cowpea per ha were not affected (Table 2). There was a positive interaction between the preceding legume crops and intercropped maize with cowpea on ear length, diameter and weight, grain yields per plant and per ha compared to the other treatments. Accordingly, the preceding cereal crop (wheat) decreased soil nutrient availability (Table 1) and increased intra-specific competition between maize plants for above and under-ground conditions which reduced potential yield of sole maize. So, these results indicate that BNF process of cowpea (the legume component) could be integrated with the residual effect of the preceding berseem or faba bean crop and thereby contributed mainly to fulfill the N requirement of maize (the cereal component) by enhancing the rhizobia growth in rhizosphere of maize roots during maize growth and development. Naturally, the fixed N by legume can be use by intercropped cereals during their growing period and this N is an important resource for the cereals [44].

3.1.5 Response of the preceding crop to mineral N fertilizer

Plant height, stem diameter, number of ears/plant, ear length, diameter and weight, grain yields per plant and per ha were affected significantly by the preceding crop x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, forage yield of cowpea per ha was not affected (Table 2). Growing maize that received 100% of the recommended mineral N fertilizer rate (285.6 kg N/ha) after harvest of the legume crops had the highest studied traits of maize compared to the other treatments. Certainly, N is the key element in increasing yield and mediates the utilization of potassium, phosphorus and other elements in plants [45]. Also, the soil fertility status is improved by activating the soil microbial biomass [46].

Table 2. Effect of the preceding crop, cropping systems, mineral N fertilizer rates and their interactions on maize yield and its attributes, as well as, cowpea yield, combined data across 2013/2014 and 2014/2015 seasons

Treatments		Plant height (cm)				Stem diameter (cm)				Ears/plant (no.)			
		100%	87.5%	75.0%	Mean	100%	87.5%	75.0%	Mean	100%	87.5%	75.0%	Mean
Berseem	Intercropping culture	292.37	287.71	268.58	282.88	2.26	2.12	2.01	2.13	1.07	1.04	0.99	1.03
	Sole culture	294.04	287.02	269.59	283.55	2.24	2.12	2.04	2.13	1.05	1.02	0.98	1.01
	Mean	293.20	287.36	269.08	283.21	2.25	2.12	2.02	2.13	1.06	1.03	0.98	1.02
Faba bean	Intercropping culture	285.46	281.99	264.31	277.25	2.21	2.07	2.00	2.09	1.05	1.02	0.98	1.01
	Sole culture	287.68	283.25	266.16	279.02	2.19	2.05	1.98	2.07	1.03	1.00	0.96	0.99
	Mean	286.57	282.62	265.23	278.14	2.20	2.06	1.99	2.08	1.04	1.01	0.97	1.00
Wheat	Intercropping culture	274.14	269.41	244.67	262.74	2.07	2.01	1.95	2.01	1.01	1.01	0.92	0.98
	Sole culture	275.79	271.16	245.55	264.16	2.05	1.97	1.93	1.98	1.00	0.99	0.91	0.96
	Mean	274.96	270.28	245.11	263.45	2.06	1.99	1.94	1.99	1.00	1.00	0.91	0.97
Average of cropping systems	Intercropping culture	283.99	279.70	259.18	274.29	2.18	2.06	1.98	2.07	1.04	1.02	0.96	1.00
	Sole culture	285.83	280.47	260.43	275.57	2.16	2.04	1.98	2.06	1.02	1.00	0.95	0.98
Average of mineral N fertilizers		284.91	280.08	259.80	274.93	2.17	2.05	1.98	2.06	1.03	1.01	0.95	0.99
L.S.D. 0.05 Preceding crop (P)					N.S.				N.S.				N.S.
L.S.D. 0.05 Cropping systems (S)					N.S.				N.S.				N.S.
L.S.D. 0.05 Mineral N fertilizer rates (N)					21.31				0.18				0.05
L.S.D. 0.05 P x S					N.S.				N.S.				N.S.
L.S.D. 0.05 P x N					23.82				0.24				0.08
L.S.D. 0.05 S x N					N.S.				N.S.				N.S.
L.S.D. 0.05 P x S x N					N.S.				N.S.				N.S.

Table 2. Continued…

Treatments		Ear length (cm)				Ear diameter (cm)				Ear weight (g)			
		100%	87.5%	75.0%	Mean	100%	87.5%	75.0%	Mean	100%	87.5%	75.0%	Mean
Berseem	Intercropping culture	21.54	21.38	20.86	21.26	5.43	5.30	4.81	5.18	222.47	209.43	186.69	206.19
	Sole culture	21.42	21.15	20.69	21.08	5.38	5.21	4.72	5.10	215.16	200.97	177.22	197.78
	Mean	21.48	21.26	20.77	21.17	5.40	5.25	4.76	5.14	218.81	205.20	181.95	201.98
Faba bean	Intercropping culture	21.49	21.30	20.78	21.19	5.40	5.20	4.73	5.11	216.14	202.38	179.86	199.46
	Sole culture	21.35	21.09	20.62	21.02	5.34	5.15	4.64	5.04	210.05	196.01	171.25	192.43
	Mean	21.42	21.19	20.70	21.10	5.37	5.17	4.68	5.07	213.09	199.19	175.55	195.94
Wheat	Intercropping culture	21.31	21.10	20.52	20.97	5.21	4.99	4.61	4.93	206.56	191.89	160.12	186.19
	Sole culture	21.22	20.97	20.41	20.86	5.13	4.90	4.49	4.84	199.12	184.73	149.45	177.76

Treatments		**Ear length (cm)**				**Ear diameter (cm)**				**Ear weight (g)**			
		100%	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**
	Mean	21.26	21.03	20.46	20.91	5.17	4.94	4.55	4.88	202.84	188.31	154.78	181.97
Average of cropping systems	Intercropping culture	21.44	21.26	20.72	21.14	5.34	5.16	4.71	5.07	215.05	201.23	175.55	197.28
	Sole culture	21.33	21.07	20.57	20.98	5.28	5.08	4.61	4.99	208.11	193.90	165.97	189.32
Average of mineral N fertilizers		21.38	21.16	20.64	21.06	5.31	5.12	4.66	5.03	211.58	197.56	170.76	193.30
L.S.D. 0.05 Preceding crop (P)					0.25				0.25				19.15
L.S.D. 0.05 Cropping systems (S)					0.23				0.21				15.33
L.S.D. 0.05 Mineral N fertilizer rates (N)					0.11				0.08				6.54
L.S.D. 0.05 P x S					0.26				0.27				20.93
L.S.D. 0.05 P x N					0.28				0.28				22.28
L.S.D. 0.05 S x N					0.24				0.22				17.09
L.S.D. 0.05 P x S x N					0.32				0.31				23.75

Table 2. Continued…

Treatments		**Grain yield/plant (g)**				**Grain yield/ha (ton)**				**Forage yield of cowpea (ton/ha)**			
		100%	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**
Berseem	Intercropping culture	232.71	218.23	184.56	211.83	8.04	7.60	7.18	7.60	16.52	17.83	17.53	17.29
	Sole culture	223.93	210.34	174.13	202.80	7.89	7.44	7.05	7.46	35.42	35.89	35.11	35.47
	Mean	228.32	214.28	179.34	207.31	7.96	7.52	7.11	7.53	25.97	26.86	26.32	26.38
Faba bean	Intercropping culture	221.10	204.76	174.33	200.06	7.87	7.56	7.01	7.48	16.50	16.76	16.91	16.72
	Sole culture	215.12	200.71	166.05	193.96	7.73	7.41	6.90	7.34	35.61	35.12	35.08	35.27
	Mean	218.11	202.73	170.19	197.01	7.80	7.48	6.95	7.41	26.05	25.94	25.99	25.99
Wheat	Intercropping culture	204.37	187.03	145.84	179.08	7.41	6.99	6.56	6.98	15.71	16.89	16.42	16.34
	Sole culture	197.72	180.44	136.24	171.46	7.27	6.83	6.41	6.83	35.29	35.11	35.02	35.14
	Mean	201.04	183.73	141.04	175.27	7.34	6.91	6.48	6.91	25.50	26.00	25.72	25.74
Average of cropping systems	Intercropping culture	219.39	203.34	168.24	196.99	7.77	7.38	6.91	7.35	16.24	17.16	16.95	16.78
	Sole culture	212.25	197.16	158.80	189.40	7.63	7.22	6.78	7.21	35.44	35.37	35.07	35.29
Average of mineral N fertilizers		215.82	200.25	163.52	193.19	7.70	7.30	6.84	7.28	25.84	26.26	26.01	26.03
L.S.D. 0.05 Preceding crop (P)					28.42				0.60				N.S.
L.S.D. 0.05 Cropping systems (S)					17.07				0.42				14.79
L.S.D. 0.05 Mineral N fertilizer rates (N)					6.91				0.12				N.S.
L.S.D. 0.05 P x S					31.55				0.64				N.S.
L.S.D. 0.05 P x N					33.14				0.69				N.S.
L.S.D. 0.05 S x N					19.78				0.45				N.S.
L.S.D. 0.05 P x S x N					36.23				0.76				N.S.

3.1.6 Response of cropping systems to mineral N fertilizer

Ear length, diameter and weight, grain yields per plant and per ha were affected significantly by cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, plant height, stem diameter, number of ears per plant and forage yield of cowpea per ha were not affected (Table 2). Obviously, intercropped maize that received 285.6 kg N/ha gave the highest ear length, diameter and weight, grain yields per plant and per ha compared to the other treatments. Conversely, sole or intercropped maize that received 214.2 kg N/ha increased intra and inter-specific competition between cowpea and maize plants, respectively, for basic growth resources especially soil N. Accordingly, the rate of photosynthetic process could not be maintained high during grain filling which reflected on grain yield of sole or intercropped maize plant as a consequence of decrease in soil N availability compared to the other treatments.

These results show that intercropping cowpea with maize interacted positively with 87.5% of the recommended mineral N fertilizer rate (249.9 kg N/ha) to decrease inter-specific competition between intercropped maize plants for basic growth resources especially soil N. It is important to mention that there were no significant differences between 285.6 and 249.9 kg N/ha on maize plants of mixed pattern. These findings imply that application of 249.9 kg N/ha for intercropped maize with cowpea furnished suitable environmental resources for maize plant to increasing inter-specific competition between maize and cowpea for fixed N. Clearly, the greater competition of maize plant for available soil N at high bean populations, when legumes were nearer to maize rows, might have stimulated root nodulation of intercropped beans [47]. Consequently, maize plant of mixed pattern that received 249.9 kg N/ha could be enhanced BNF process of cowpea to fix about 12.5% N of maize requirements where nodulation and N fixation by legumes is adversely affected by higher rates of fertilizer N [48]. Finally, El – Shamy et al. [40] showed that maize plant of mixed pattern that received the recommended N rate did not achieve the highest grain and total yields/ha. They added that the recommended N rate to maize plant of mixed stand affected negatively rhizobia activity in rhizosphere of maize roots and efficiency of BNF by adjacent legume plants.

3.1.7 Response of the preceding crop to cropping systems and mineral N fertilizer

Ear length, diameter and weight, grain yields per plant and per ha were affected significantly by the preceding crop x cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons, meanwhile, plant height, stem diameter, number of ears per plant and forage yield of cowpea per ha were not affected (Table 2). Intercropping cowpea with maize that received 100 or 87.5% of the recommended mineral N fertilizer rate after legume crops harvest gave the highest ear length, diameter and weight, grain yields per plant and per ha compared to the other treatments. It is important to mention that intercropped maize plants that received 249.9 kg N/ha after harvest of the legume crops reached the same significance level of intercropped maize plants that received the highest mineral N fertilizer rate after harvest of the legume crops.

These results reveal that there was positive interaction effect of the preceding legume crops and intercropped maize plants that received 249.9 kg N/ha because of nitrate could be inhibited nitrogenase activity in the legume plant nodules [49]. It is known that legumes have two sources of N nutrition – symbiotic N fixation of atmospheric molecular N in symbiosis with *Rhizobium* or *Bradyrhizobium* sp. and assimilation of soil N (mainly in the form of nitrates), using the enzyme nitrate reductase [50]. Thus, the bacteria that actually fixed the N become lazy and N fixing declines [51]. Accordingly, the efficiency of BNF process could not be enhanced by the interaction among the preceding legume (berseem or faba bean) crop, intercropped maize and the highest mineral N fertilizer rate.

3.2 Quality of Maize Grains

3.2.1 Effect of the preceding crop

Quality of maize grains (N, oil and protein contents) was affected significantly by the preceding crop in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). Berseem residues increased grain N and protein contents but it decreased grain oil content compared to those by faba bean or wheat. These results could be due to the increase in soil N content after berseem cutting (Table 1) which increased absorption N uptake from soil by maize roots to sink tissues (grains), especially N supply to maize grains influences on the accumulation of proteins [52].

3.2.2 Effect of cropping systems

Quality of maize grains (N, oil and protein contents) was affected significantly by cropping systems in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). Growing cowpea in the other side of maize ridge increased grain N and protein content by 1.47 and 1.16%, respectively, compared with those of sole maize, but it decreased grain oil content. These results could be due to maize plant benefited from BNF process of cowpea which reflected positivity on grain N and protein contents.

3.2.3 Effect of mineral N fertilizer

Quality of maize grains (N, oil and protein contents) was affected significantly by mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). It is observed that Increasing mineral N fertilizer from 214.2 to 285.6 kg N/ha increased grain N and protein contents by 5.26 and 6.00%, respectively.

Naturally, there was growth disadvantage of maize plant with the application of 249.9 or 214.2 kg N/ha as a result of decreasing soil N availability and hence these rates of mineral N fertilizer were not able to satisfy the requirement of maize growth and development. Similar results were obtained by Sarwar [8] who indicated that the protein content was increased significantly with the successive increase of N.

3.2.4 Response of the preceding crop to cropping systems

Quality of maize grains (N, oil and protein contents) was affected significantly by the preceding crop x cropping systems in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). It seems that there was a positive effect of the preceding berseem crop interacted with cowpea on quality of maize grains. Berseem residues improved soil N availability (Table 1) that decreased intra-specific competition between maize plants for above and under-ground conditions and increased potential yield of intercropped maize. So, these results indicate that BNF process of cowpea (the legume component) could be integrated with the residual effect of the preceding berseem crop and thereby contributed mainly to fulfill the N requirement of maize (the cereal component) by enhancing the rhizobia growth in rhizosphere of maize roots during maize growth and development.

3.2.5 Response of the preceding crop to mineral N fertilizer

Quality of maize grains (N, oil and protein contents) was affected significantly by the preceded winter field crops x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). Growing maize with the application of 285.6 kg N/ha had the highest grain N and protein contents and the lowest grain oil content compared to the other treatments.

3.2.6 Response of cropping systems to mineral N fertilizer

Quality of maize grains (N, oil and protein contents) was affected significantly by cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). Intercropped maize plants with the application of 285.6 kg N/ha gave the highest grain N and protein contents and the lowest grain oil content compared to the other treatments. Conversely, maize plants of sole culture 214.2 kg N/ha increased inter-specific competition between maize plants for basic growth resources especially soil N which reflected on grain N, oil and protein contents. It is expected that intercropping cowpea with maize plants that received 87.5% of the recommended N rate (249.9 kg N/ha) promoted rhizobia growth in rhizosphere of maize root. Vegetative growth and development of maize plant benefited from the available fixed N by intercropped legume which reflected positively on the ear leaf N content [40].

3.2.7 Response of the preceding crop to cropping systems and mineral N fertilizer

Quality of maize grains (N, oil and protein contents) was affected significantly by the preceding crop x cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Table 3). Intercropping cowpea with maize that received 100 or 87.5% of the recommended mineral N fertilizer rate after berseem cutting had the highest grain N and protein contents and the lowest oil content compared to the other treatments. These data show that there was effect *($P \leq 0.05$)* of the preceding crop x cropping systems x mineral N fertilizer rates on quality of maize grains.

Table 3. Effect of the preceding crop, cropping systems, mineral N fertilizer rates and their interactions on quality of maize grains, combined data across 2013/2014 and 2014/2015 seasons

Treatments		Grain N content (%)				Grain oil content (%)				Grain protein content (%)			
		100%	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**	**100%**	**87.5%**	**75.0%**	**Mean**
Berseem	Intercropping culture	1.45	1.44	1.38	1.42	10.22	10.25	10.32	10.26	9.06	9.00	8.62	8.89
	Sole culture	1.45	1.42	1.36	1.41	10.27	10.29	10.38	10.31	9.06	8.87	8.50	8.81
	Mean	1.45	1.43	1.37	1.41	10.24	10.27	10.35	10.28	9.06	8.93	8.56	8.85
Faba bean	Intercropping culture	1.42	1.40	1.36	1.39	10.32	10.34	10.43	10.36	8.87	8.75	8.50	8.70
	Sole culture	1.41	1.40	1.32	1.37	10.38	10.42	10.49	10.43	8.81	8.75	8.25	8.60
	Mean	1.41	1.40	1.34	1.38	10.35	10.38	10.46	10.39	8.84	8.75	8.37	8.65
Wheat	Intercropping culture	1.38	1.36	1.31	1.35	10.52	10.54	10.60	10.55	8.62	8.50	8.18	8.43
	Sole culture	1.36	1.34	1.27	1.32	10.56	10.60	10.68	10.61	8.50	8.37	7.93	8.26
	Mean	1.37	1.35	1.29	1.33	10.54	10.57	10.64	10.58	8.56	8.43	8.05	8.34
Average of cropping systems	Intercropping culture	1.41	1.40	1.35	1.38	10.35	10.37	10.45	10.39	8.85	8.75	8.43	8.67
	Sole culture	1.40	1.38	1.31	1.36	10.40	10.43	10.51	10.44	8.79	8.66	8.22	8.55
Average of mineral N fertilizers		1.40	1.39	1.33	1.37	10.37	10.40	10.48	10.41	8.82	8.70	8.32	8.61
L.S.D. 0.05 Preceding crop (P)					0.03				0.09				0.17
L.S.D. 0.05 Cropping systems (S)					0.02				0.05				0.12
L.S.D. 0.05 Mineral N fertilizer rates (N)					0.01				0.03				0.08
L.S.D. 0.05 P x S					0.04				0.11				0.19
L.S.D. 0.05 P x N					0.06				0.13				0.21
L.S.D. 0.05 S x N					0.03				0.08				0.15
L.S.D. 0.05 P x S x N					0.07				0.15				0.24

3.3 Nitrogen Use Efficiency (NUE)

3.3.1 Effect of the preceding crop

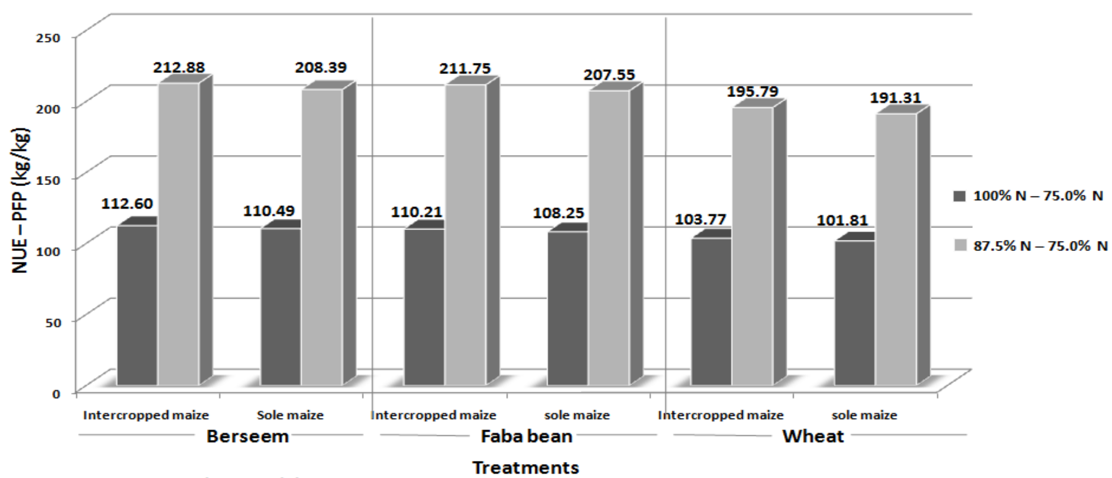
Partial factor productivity (NUE–PFP) expressed as crop yield per unit of N applied (Roberts, 2008) are indicative of the degree of economic and environmental efficiency in use of nutrient inputs. In this study, NUE ranges from 101.81 to 212.88 kg grain yield per kg nutrient applied (Fig. 1). NUE values of 40–80 kg/kg are usual with values > 60 kg/kg for NUE being common in well–managed systems or at low levels of N use, or at low soil N supply [14]. Berseem residues increased NUE of maize plants compared to that of the other preceded crops (Fig. 1). These results could be due to the increase in soil N content after berseem cutting (Table 1) which increased absorption N uptake from soil by maize roots. Consequently, this status led to more assimilation into amino acids that serve as N carriers throughout the plant and N transport from source to sink tissues throughout plant development, especially during the grain filling period (Table 2).

3.3.2 Effect of cropping systems

NUE was affected significantly by cropping systems in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). Growing cowpea in the other side of maize ridge increased NUE by 2.06% compared with that of sole maize. These results could be due to maize plant benefited from BNF process of cowpea that reflected positively on grain N content (Table 3). Similar results were obtained by Gao et al. [31] who showed that N uptake of maize as an intercrop was significantly greater than those of maize as a sole crop. Also, El-Shamy et al. [40] showed that legume crop improved N use efficiency (NUE) for maize plant of mixed pattern. Finally, Zhang et al. [53] indicated that intercropping systems reduced use of N fertilizer per unit land area and increased relative biomass of intercropped maize, due to promoted photosynthetic efficiency of border rows and N utilization during symbiotic period.

3.3.3 Effect of mineral N fertilizer

NUE was affected significantly by mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). Maize plants with the application of 87.5% of the recommended mineral N fertilizer rate increased (*P≤0.05*) NUE by 89.70 % compared to that of maize plants with the application of 100% of the recommended mineral N fertilizer rate. It is observed that NUE values emerging from this study apply to low levels of N use, or at low soil N supply and contributed positively in increase of photosynthesis process efficiency and consequently grain yield/plant (Table 2).



L.S.D. 0.05 Preceding crop (P) 1.42
L.S.D. 0.05 Cropping systems (S) 1.24
L.S.D. 0.05 Mineral N fertilizer rate (N) 1.09
L.S.D. 0.05 P x S 1.55
L.S.D. 0.05 P x N 1.62
L.S.D. 0.05 S x N 1.33
L.S.D. 0.05 P x S x N 1.66

Fig. 1. NUE as affected by the preceding crop, cropping systems, mineral N fertilizer rates and their interactions, combined data across 2013/2014 and 2014/2015 seasons

Similar results were obtained by El-Shamy et al. [40] who found that adding 83.33% of the recommended mineral N fertilizer rate N to maize plant increased ($P≤0.05$) NUE by 97.74 percent compared to those that received 100% of the recommended mineral N fertilizer rate.

3.3.4 Response of the preceding crop to cropping systems

NUE was affected significantly by the preceding crop x cropping systems in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). There was a positive effect of berseem residues with cowpea on NUE of intercropped maize compared to the other treatments. So, these results could be attributed to BNF process of cowpea integrated with the residual effect of the preceding berseem crop and thereby contributed mainly to fulfill the N requirement of maize.

Conversely, maize plants that followed wheat crop had the lowest NUE compared to the other treatments. These results could be due to the preceding wheat crop decreased soil nutrient availability (Table 1) which increased intra-specific competition between maize plants for above and under-ground conditions and reduced potential yield of sole maize.

3.3.5 Response of the preceding crop to mineral N fertilizer

NUE was affected significantly by the preceding crop x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). Growing maize with the application of 100% of the recommended mineral N fertilizer rate (285.6 kg N/ha) after berseem cutting had the highest NUE, meanwhile, maize plants that received 75% of the recommended mineral N fertilizer rate (214.2 kg N/ha) after wheat harvest had the lowest NUE compared to the other treatments. It is expected that the preceding wheat crop interacted with 214.2 kg N/ha and resulted in a greater competition between maize plants for available soil N which affected negatively N uptake of maize plant.

3.3.6 Response of cropping systems to mineral N fertilizer

NUE was affected significantly by cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). Intercropping cowpea with maize plants with the application of 87.5% of the recommended mineral N fertilizer rate had the highest NUE compared to the other treatments. These data may be due to the application of 87.5 % of the recommended mineral N fertilizer rate promoted rhizobia growth in rhizosphere of intercropped maize roots which reflected positively on N uptake and IAA content in tissues of maize plant and contributed strongly with enhancing efficiency of photosynthesis process. Intercropping cowpea with maize that received 100% of the recommended mineral N fertilizer rate could be affected negatively rhizobia activity in rhizosphere of intercropped cowpea roots which reflected negatively on NUE of intercropped maize plant. These results are in parallel with those obtained by El-Shamy et al. [40] who found that adding 83.33% of the recommended N rate to maize plants promoted rhizobia growth in rhizosphere of maize roots and increased N uptake and IAA content in tissues of maize plant which increased NUE of intercropped maize compared to those received the full mineral N fertilizer rate.

3.3.7 Response of the preceding crop to cropping systems and mineral N fertilizer

NUE was affected significantly by the preceding crop x cropping systems x mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 1). Intercropping cowpea with maize that received 100 or 87.5% of the recommended mineral N fertilizer rate after berseem cutting had the highest NUE, meanwhile, maize plants of sole culture that received 75.0% of the recommended mineral N fertilizer rate after wheat harvest had the lowest NUE compared to the other treatments. These results reveal that there was advantage of intercropping cowpea with maize that received 87.5% of the recommended mineral N fertilize rate after berseem cutting as a result of increasing efficiency of BNF process of cowpea. Intercropping cowpea with maize that received 100% of the recommended mineral N fertilizer rate after berseem cutting did not achieve the highest NUE because of nitrate could be inhibited nitrogenase activity in the legume plant nodules [49].

3.4 Competitive Relationships

3.4.1 Land equivalent ratio (LER)

3.4.1.1 Effect of the preceding crop

The values of LER were estimated by using data of recommended sole cultures of both crops.

Intercropping cowpea with maize increased LER as compared to sole cultures of both crops in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). It was ranged from 1.36 (by intercropping cowpea with maize that received 214.2 kg N/ha after wheat harvest) to 1.47 (by intercropping cowpea with maize that received 285.6 kg N/ha after berseem cutting). The results showed that maize was superior in the intercrop system where the relative yield was increased than those of sole culture, meanwhile cowpea was inferior companion crop where the relative yield was decreased than those of sole culture in the combined analysis.

LER was affected significantly by the preceding crop in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). The advantage of the highest LER by intercropping cowpea with maize after harvest of the legume crops over the others could be due to residual effect of the legume crops improved soil nutrient availability (Table 1) for intercropping cowpea (50 % of sole cowpea plant density) with maize (100% of sole maize plant density) and reflected positively on relative yields of both crops. These results are in accordance with those obtained by HamdAlla et al. [6] who concluded that the actual productivity was higher than expected productivity. Also, Abd El-Salam and Abd El-Lateef [54] concluded that maize-cowpea intercropping increase land use efficiency by 12- 14% compared with each crop grown alone.

3.4.1.2 Effect of mineral N fertilizer

LER was affected significantly by mineral N fertilizer in the combined data across 213/2014 and 2014/2015 seasons (Fig. 2). LER was increased by increasing mineral N fertilizer rates from 214.2 to 285.6 kg N/ha. These results show that the decreasing mineral N fertilizer rate from 285.6 to 214.2 kg N/ha decreased soil N availability (Table 1) and increased intra-specific competition between maize plants for basic growth resources especially soil N.

3.4.1.3 Response of the preceding crop to mineral N fertilizer

LER was affected significantly by the interaction between the preceding crop and mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 2). LER was increased by application of 285.6 or 249.9 kg N/ha to maize plants after the preceding legume crops. These results may b due to the interaction between the preceding legume crops and 285.6 or 249.9 kg N/ha increased N content in tissues of maize plants especially N is the key element in increasing yield and mediates the utilization of potassium, phosphorus and other elements [45].

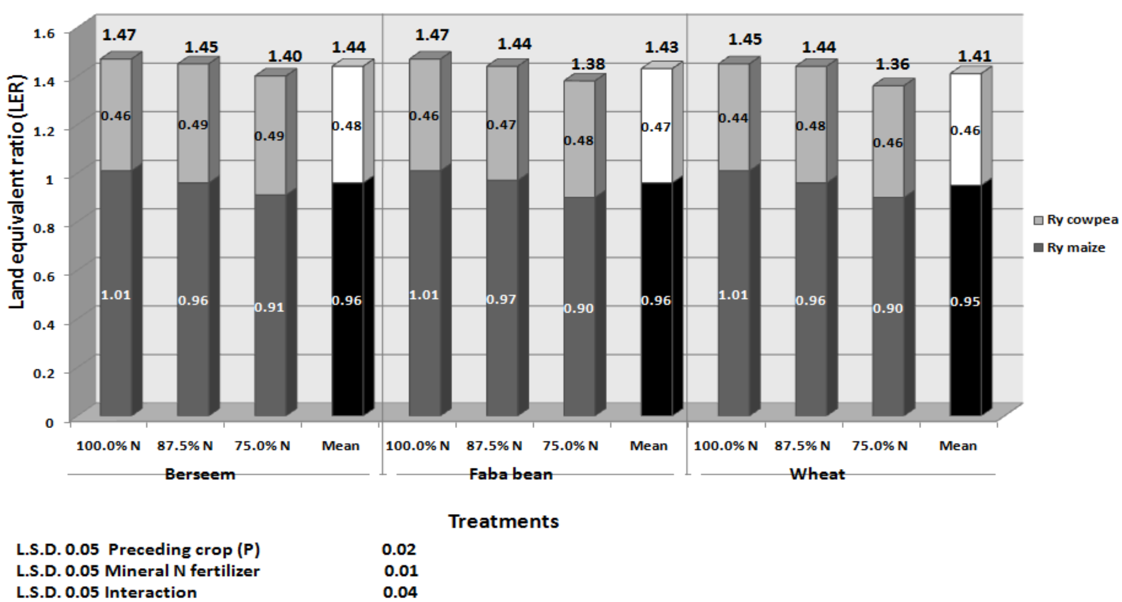


Fig. 2. LER as affected by the preceding crop, cropping systems, mineral N fertilizer rates and their interactions, combined data across 2013/2014 and 2014/2015 seasons

3.4.2 Land Equivalent Coefficient (LEC)

3.4.2.1 Effect of the preceding crop

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 the preceding crop in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). Intercropping cowpea with maize increased LER as compared to sole cultures of both crops. The advantages of the highest LEC by intercropping cowpea with maize that followed legume crops over the others could be due to the preceding legume crops improved soil nutrient availability (Table 1) for intercropping cowpea with maize which reflected positively on relative yields of both crops.

3.4.2.2 Effect of mineral N fertilizer

LEC was affected significantly by mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). LEC was increased by increasing mineral N fertilizer rates from 214.2 to 285.6 kg N/ha. These results show that the decreasing mineral N fertilizer rate from 285.6 to 214.2 kg N/ha decreased soil N availability (Table 1) and increased intra-specific competition between maize plants for basic growth resources especially soil N.

3.4.2.3 Response of the preceding crop to mineral N fertilizer

LEC was affected significantly by the interaction between the preceding crop and mineral N fertilizer in the combined data across 2013/2014 and 2014/2015 seasons (Fig. 3). LEC was increased by application of 285.6 or 249.9 kg N/ha to maize plants after the preceding legume crops. These results may b due to the interaction between the preceding legume crops and 285.6 or 249.9 kg N/ha increased N content in tissues of maize plants especially soil N (Table 1).

3.5 Intercropping Economic Advantage

The economic performance of the intercropping was evaluated to determine if maize and cowpea combined yields are high enough for the farmers to adopt this system. The averages of monetary advantage index (MAI) values of intercropping cowpea with maize that received 100 or 87.5% of the recommended mineral N fertilizer rate after berseem cutting were higher than the other treatments (Fig. 4). Differences between the highest and the lowest values of MAI were 274 US$ in the combined data across 2013/2014 and 2014/2015 seasons. On the other hand, there were gradual and consistent decreases in MAI values with deceasing mineral N fertilizer rate from 100 to 75% of the recommended mineral N fertilizer rate of intercropped maize with cowpea. Intercropping cowpea with maize that received 87.5% of the recommended mineral N fertilizer

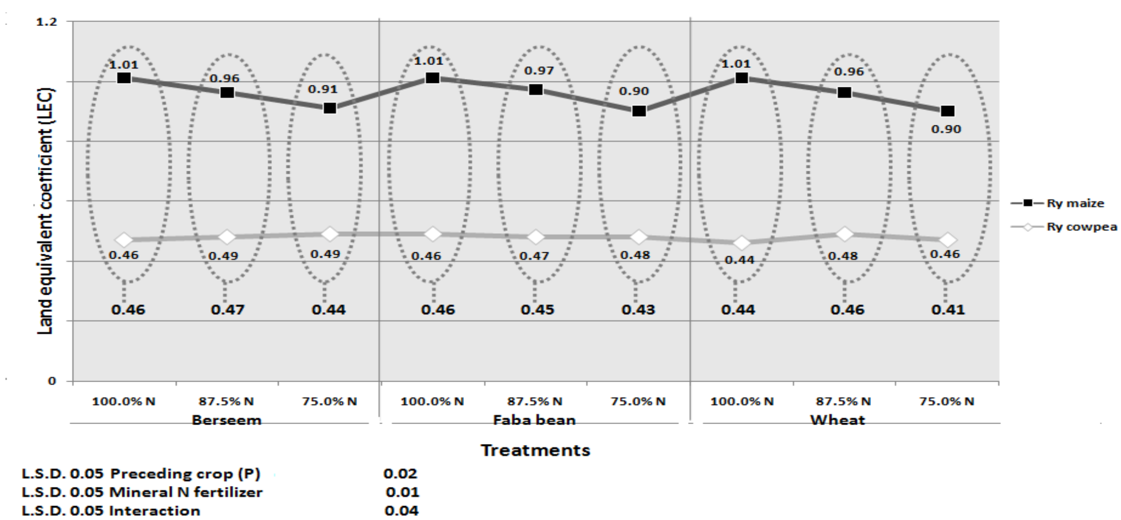


Fig. 3. LEC as affected by the preceding crop, cropping systems, mineral N fertilizer rates and their interactions, combined data across 2013/2014 and 2014/2015 seasons

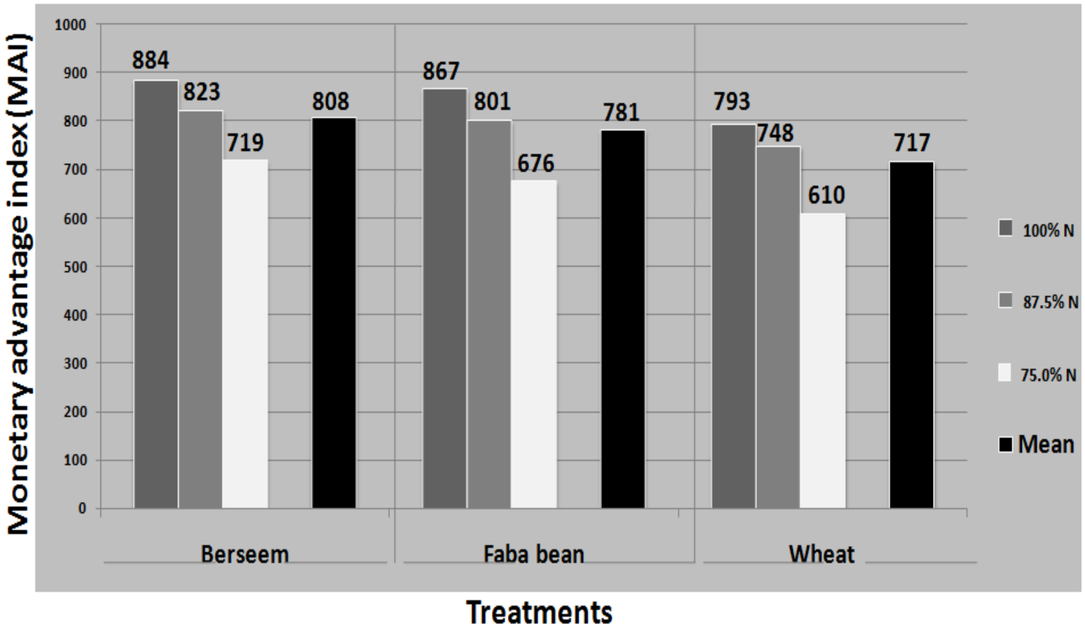


Fig. 4. MAI as affected by the preceding crop, cropping systems, mineral N fertilizer rates and their interactions, combined data across 2013/2014 and 2014/2015 seasons

rate after berseem cutting resulted in high MAI and could be recommended. These results are in parallel with those observed by HamdAlla et al. [6] who concluded that values of MAI were 2097.28, 2607.95 and 2360.80 in both seasons and the combined analyses.

4. CONCLUSION

It could be concluded that intercropping cowpea with maize that received 87.5% of the recommended mineral N fertilizer after berseem cutting compensated 12.5% N of maize requirements and achieved desirable yield with good yield quality under Egyptian conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Buresh RJ, Sanchez PA, Calhoun F. Replenishing soil fertility in Africa. SSSA Spec. Publ. 51. SSSA and ASA, Madison, WI; 1997.
2. Sonnewald U. Plant physiology preview. www.plant.org, American Society of Plant Biologists; 2012.
3. Bulletin of Statistical Cost Production and Net Return. Summer and Nili field crops and vegetables and fruit, agriculture statistics and economic sector, Ministry of Egyptian Agriculture and Land Reclamation, Part (2); 2014.
4. Shu-Min LI, Fan WU. Nitrogen uptake facilitation in soybean/maize intercropping system inoculated with *rhizobium* and *arbuscular mycorrhizal* fungi. Acta Metallurgica Sinica. 2011;17(1):110–116. DOI: 10.11674/zwyf.2011.0115
5. Latati M, Pansu M, Drevon JJ, Ounane SM. Advantage of intercropping maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) on yield and nitrogen uptake in Northeast Algeria. Int. J. Res. Appl. Sci. 2013;01:1–7.
6. HamdAlla WA, Shalaby EM, Dawood RA, Zohry AA. Effect of cowpea (*Vigna unguiculata* L.) with maize (*Zea mays* L.) intercropping on yield and its components. Int. J. Biological, Food, Veterinary and Agric. Eng. 2014;8(11):1200–1206.
7. Sabata RJ, Mason SC. Corn hybrid interactions with soil nitrogen level and water regime. J. Production Agric. 1992;5: 137–142.
8. Sarwar M. Effect of different levels of N – fertilizers on the yield and quality of maize. Pak. J. Agric. Sci. 1993;30(1):99–101.

9. Cheetham H, Millner J, Hardacre A. The effect of nitrogen fertilisation on maize grain quality and yield. Agron. N.Z. 2006; 36:71–84.
10. Blanco-Canqui H, Lal R. Crop residue removal impacts on soil productivity and environmental quality. Critical Reviews in Plant Sci. 2009;28:139–163.
11. Chapman HD, Pratt PE. Methods of analysis for soil, plant and water. Division Agric. Sci., California Univ., U.S.A; 1961.
12. AOAC. Official methods of analysis of A.O.A.C. International. 17th ed. By Horwitz, W. Suite (ed.) 2000;2(41):66–68.
13. Sadasivam S, Manickam A. Biochemical methods. 2nd edn. New Age International (p) Ltd. Publisher, New Delhi. 1997;5–207.
14. Dobermann A. Nutrient use efficiency – Measurement and management. Proceedings of IFA International Workshop on Fertilizer Best Management Practices, Brussels, Belgium; 2007.
15. Weber EP, Day FP. Effect of nitrogen fertilization on the phenology of roots in a barrier island sand dune community. Plant and Soil. 1996;182:139–148.
16. Brye KR, Norman JM, Nordheim EV, Gower ST, Bundy LG. Refinements to an in-Situ soil core technique for measuring net nitrogen mineralization in moist, fertilized agricultural soil. Agron. J. 2002; 94:864–869.
17. Mead R, Willey RW. The concept of a "land equivalent ratio" and advantages in yields from intercropping. Exp. Agric. 1980; 16:217–28.
18. Adetiloye PO, Ezedinma FOC, Okigbo BN. A land equivalent coefficient concept for the evaluation of competitive and productive interactions on simple complex mixtures. Ecological Modelling. 1983;19: 27-39.
19. Willey RW. Intercropping its importance and research needs. Part I: Competition and yield advantages. Field Crops Abst. 1979;32:1–10.
20. Freed RD. MSTATC Microcomputer Statistical Program. Michigan State Univ. East Lansing, Michigan, USA; 1991.
21. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Eilley and Sons, Inc. New York; 1984.
22. Viola GM, Ganesh S, Reddy S, Kumar CVS. Studies on correlation and path coefficient analysis of elite baby corn (*Zea mays* L.). Indian Prog. Agri. 2003;3(1-2): 22–25.
23. Chalk PM. Dynamics of biologically fixed N in legume-cereal rotations: A review. Aust. J. Agric. Res. 1998;49:303–316.
24. Eleweanya NP, Uguru MI, Eneobong EE, Okocha PI. Correlation and path coefficient analysis of grain yield related characters in maize (*Zea mays* L.) under umudike conditions of South Eastern Nigeria. J. Agric., Food, Environ. and Extension. 2005;4(1):24–28.
25. Arya RL, Varshney JG, Kumar L. Effect of integrated nutrient application in chickpea + mustard intercropping system in the semiarid tropics of North India. Commun. Soil Sci. Plant Anal. 2007;38:229–240.
26. Olesen JE, Hansen EM, Askegaard M, Rasmussen IA. The value of catch crops and organic manures for spring barley in organic arable farming. Field Crops Res. 2007;100:168–178.
27. Bloem AA, Barnard RO. Effect of annual legumes on soil nitrogen and on the subsequent yield of maize and grain sorghum. South Afr. J. Plant and Soil. 2001;18(2):56–61.
28. Ali W, Jan A, Hassan A, Abbas A, Hussain A, Ali M, Zuhair SA, Hussain A. Residual effect of preceding legumes and nitrogen levels on subsequent maize. Int. J. Agron. and Agric. Res. 2015;7(1):78–85.
29. Lamlom MM, Abdel-Wahab ShI, Abdel-Wahab TI, Gendy EK. Residual effects of some preceded winter field crops on productivity of intercropped soybean with three maize cultivars. American J. BioSci. 2015;3(6):226–242.
30. Wade LJ, Norris CP, Walsh PA. Effects of suboptimal plant density and non-uniformity in plant spacing on grain yield of rain-grown sunflower. Aust J. Experimental Agric. 1988;28:617–622.
31. Gao Y, Duan A, Qiu X, Liu Z, Sun J, Zhang J, Wang H. Distribution of roots and root length density in a maize/soybean strip intercropping system. Agric. Water Management. 2010;98:199–212.
32. Eaglesham ARJ, Ayanaba A, Rao VR, Eskew DL. Improving the nitrogen nutrition of maize by intercropping with cowpea. Soil Biology and Biochemistry, Oxford. 1981;13:169–171.
33. Bonetti R. Transferencia de nitrogenio do feijao para o milho consorciado: avaliacao

pelo metodo de diluicao isotopica do 15N e efeito da associacao micorrizica. 1991. 63 f. Tese (Doutorado em Agronomia) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba; 1991.

34. Wiehe W, Hoflich G. Survival of plant growth promoting rhizosphere bacteria in the rhizosphere of different crops and migration to non-inoculated plants under field conditions in North-East Germany. Microbiological Res. 1995;150:201–206.
35. Dreccer MF, Oijen VM, Schapendonk AHCM, Pot CS, Rabbinge R. Dynamics of vertical leaf nitrogen distribution in a vegetative wheat canopy: Impact on canopy photosynthesis. Ann. Botany. 2000;86:821-831.
36. Ghannoum O, Evans JR, Caemmerer SV. Nitrogen and water use efficiency of c_4 plants. In: Raghavendra AS, Sage RF, (eds.), C_4 Photosynthesis and Related CO_2 Concentrating Mechanisms. 2011;129-146.
37. Alimohammadi I, Nassiri P, Behzad M, Hosseini MR. Reliability analysis of traffic noise estimates in highways of Tehran by Monte Carlo simulation method. Iran J. Environ. Health Sci. & Eng. 2005;2(4):229–236.
38. Wareing PF, Khalifa MM, Treharne KJ. Rate-limiting processes in photosynthesis at saturating light intensities. Nature. 1968;222:453-457.
39. Nooden LD, Leopold AC. Phytohormones and the endogenous regulation of senescence and abscission. In phytohomones and related compounds, a comprehensive Treatise. Vol. 2: Phytohormones and the Development of Higher Plants, Elsevier, Amsterdam. 1978; 329-370.
40. El-Shamy Moshira A, Abdel-Wahab TI, Abdel-Wahab ShI, Ragheb SB. Advantages of intercropping soybean with maize under two maize plant distributions and three mineral nitrogen fertilizer rates. Adv. Biosci. and Bioeng. 2015;3(4):30–48.
41. Bojović B, Marković A. Correlation between nitrogen and chlorophyll content in wheat (*Triticum eastivum* L.). Kragujevac J. Sci. 2009;31:69-74.
42. Hokmalipour S, Darbandi MH. Effects of nitrogen fertilizer on chlorophyll content and other leaf Indicate in three cultivars of maize (*Zea mays* L.). World Appl. Sci. J. 2011;15(12):1780-1785.
43. El-Shamy Moshira A, Abdel-Wahab TI, Abdel-Wahab ShI, Ragheb SB. Efficiency of intercropping soybean with corn under two corn plant distributions and three mineral nitrogen fertilizer rates. The 8th International Conf. on Technology and Sustainable Development in the Third Millennium, 22 – 24 November 2014, El-Montaza Sheraton, Alexandria, Egypt; 2014.
44. Shen QR, Chu GX. Bi-directional nitrogen transfer in an intercropping system of peanut with rice cultivated in aerobic soil. Biology and Fertility of Soils. 2004;40:81-87.
45. Brady NC. The nature and properties of soil. 9th ed. Macmillan Publishing Co.: USA; 1984.
46. Belay AA, Classens S, Wehner FC, De Beer JM. Influence of residual manure on selected nutrient elements and microbial composition of soil under long term crop rotation. South Afr. J. Plant and Soil. 2001;18:1–6.
47. Abaidoo RC, Kessel CV. ^{15}N uptake, N_2 – fixation and rhizobial interstrain competition in soybean and bean, intercropped with maize. Soil Mot Biochem. 1989;21(1):155–159.
48. Dogra RC, Dudeja SS. Fertilizer N and nitrogen fixation in legume – Rhizobium symbiosis. Ann Biology. 1993;9(2):149–164.
49. Streeter JG. Inhibition of legume nodule formation and N_2 fixation by nitrate. CRC Critical Reviews in Plant Sci. 1988;7:1–23.
50. Arrese–Igor C, Garsia–Plazaola J, Hernandez A, Aparicio–Tejo M. Effect of low nitrate supply to nodulated lucerne on time course of activities of enzymes involved in inorganic nitrogen metabolism. Physiologia Plantarum. 1990;80:185–190.
51. Braunwart K, Putnam D, Fohner G. Alternative annual forages – Now and in the future. Proceedings of 31st California Alfalfa and Forage Symposium, Modesto, CA, UC Cooperative Extension; 2001. University of California, Davis 95616.
52. Tsai CL, Dweikat I, Tsai CY. Effects of source supply and sink demand on the carbon and nitrogen ratio in maize kernels. Maydica. 1990;35:391–397.

53. Zhang Y, Liu J, Zhang J, Liu H, Liu S, Zhai L, Wang H, Lei Q, Ren T, Yin C. Row ratios of intercropping maize and soybean can affect agronomic efficiency of the system and subsequent wheat. PLoS One. 2015;10(6):e0129245

54. Abd El-Salam M, Abd El-Lateef E. Effect of maize – Cowpea intercropping on light interception, yield and land use efficiency. 4th Inter. Conf. on Agric. & Hort., 13 – 15 July, Beijing, China; 2015.

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