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Response of Intercropping Cowpea with Maize to Potassium Fertilizer and Foliar Application of Boron on the Productivity of Both Crops

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ABSTRACT

Field trials were conducted at Sers El-Layin Agriculture Research Station, Agricultural Research Center (ARC), Minufiya Governorate, Egypt, during the 2021 and 2022 seasons. The current study evaluates the response of intercropping system cowpea/maize to potassium fertilizer and boron foliar application on the productivity of both crops and monetary advantage. The experiment was laid out in a randomized complete block design using a split-plot arrangement with three replicates. Three potassium fertilizer levels (0, 30 and 60 kg/fed) were assigned to the main plots. while the sub-plots were allocated to three foliar applications of boron levels (0, 350 and 700 g/fed). These results indicated that the application of Potassium 60 kg/fed + Boron 700 g/fed produced the maximum yield and its maize components, as well as fresh forage of cowpea as compared to the other treatments. Competitive proportion and yield advantages indicated that all treatments had higher productivity advantages compared to monoculture. Maximum values of land equivalent ratio (1.70), monetary advantage index (8672 L.E./ fed), as well as gross revenue (21061 L.E./fed) were obtained when cowpea intercropped with maize with combined fertilization (60 kg/fed of K + 700 g/fed of B) compared to the gross revenue of the sole cropping of maize and cowpea (15070 and 8079 L.E. fed^{-1}), respectively. Thus, applied at 60 Kg/fed of potassium and 700 g/fed of boron is considered appropriate and economical during intercropping of cowpea and maize to improve crop production and provide economic advantages for small farmers.

Keywords: Maize; Potassium; Boron; Foliar application; Intercropping.

INTRODUCTION

According to the rapidly increasing population, the little amount of cultivated land, and the decreasing quantity of fresh irrigation water, one of the biggest problems people are currently facing is the issue of food for the world as a whole. As a result, developing countries like Egypt are faced with a more serious sustainable agriculture challenge. The utilization of environmental resources must always expand with the growth population. Therefore, intercropping systems are one of the solutions to this issue. Intercropping is the practice of cultivating a yield than monoculture within one year in the same field and has benefits such as increased productivity per unit per year, increased cash flow, increased nitrogen, increased the efficiency of water use and reduced loss during not having the benefit of cultivation (Olubode, *et al.* 2015). The shortage of water resources in Egypt is one of the most urgent causes of water challenges in the future. nevertheless, cropping system is necessary to use to face world demands would need to rise main crops in 2030 will require an increase in the area where they are harvested by 40%, and in parallel, the amount of water used for irrigation will need to rise by 14%. (UNESCO, 2006). After rice and wheat, maize is the third-most major cereal crop in Egypt. Maize (*Zea mays* L.) is essential for human and animal consumption as it is a major source of carbohydrates and a moderate supply of protein. as well as being essential for many different manufacturing processes, including oil and starch. Cowpea (*Vigna sinensis* L.) is an important crop of legumes. It serves as both a human and animal's principal source of plant protein. Cowpea fixes nitrogen in the soil and be used as a cover crop. Intercropping maize with cowpea showed maximal potentiality and resulted in higher values for most traits of maize, whereas decreased the yield of fresh cowpea compared to solid cowpea. Moreover, (LER) was 1.65 when intercropped cowpea with maize. Cowpea (A) was -0.45 and maize (A) was 0.45. This indicated that the major crop was maize rather than cowpea. The (MAI) was 2360.80. Additionally, in such an agroecosystem, legume crops like cowpea can serve as a reservoir for natural biological control viz., *Coccinella setempunctata*, *Chrysopyrla vulgaris*, *Coccinella undecimpunctata*, *Syrphus corolla* and *Paederus alfierii*. (Hamdalla *et al.* 2014). With few exceptions, intercropping cowpea and maize produced a great yield of maize and its attributes. The Yellow hybrid SC 168 provided the highest yield and its characteristics. (El-Ghobashi *et al.* 2020). Cowpea intercropped with maize have the potential to reduce interspecies competition, improve plant density and raising net profits and productivity (Singh and Ajeigbe, (2007), Asiwe and Madimabe (2020) and Asiwe *et al.* (2021). The values of land equivalent coefficient and land equivalent ratio in intercropping systems (maize/cowpea) were bigger 0.25 and 1.00, respectively. (El-Ghobashi *et al.* 2018). Aggressivity (A) and competitive ratio (CR) are two different competition indices that showed maize to be more dominant than common beans. Nevertheless, the intercropping systems (maize + common beans) increased the economic advantage viz., MAI compared to sole culture. (El-Mehy *et al.* 2023). Abdel-Wahab *et al.* (2016) Found that Plant height was not affected significantly by cropping systems. However, cropping systems have significant effects on ear diameter, ear

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length, ear weight of maize and forage production of cowpea per hectare. Intercropping cowpea with maize in the same ridge was increased grain yield/ha in comparison to solid maize. Cowpea yield was decreased by 52.45% as compared to sole cowpea. Potassium (K) is a large important, and essential nutrient for plant growth. (K) can maximize plant growth and has an impact on how the soil and plants interact (Xie *et al.* 2011). It serves as a co-factor for more than 40 enzymes that are directly related to metabolic processes in addition to being a crucial mineral for the growth and development of crops. (Marschner, 2011). As a result of its application, opening and closing of stomatal, rate of transpiration, rate of photosynthetic, grain production (Aslam *et al.* 2014). Ouda *et al.* (2018) demonstrated that the maximum of the majority values of the intercrop yield was achieved with 114 K_2O kg ha^{-1}. Brown *et al.* 2002 boron (B) is an essential component in the development and growth of a crop. A low level of boron hurts crop quality attributes and the production of grains (Cakmak, 2002 and Shukla *et al.* 2015). Considered to be a component of the plant cell walls, boron serves as a structural element for the stability and integrity of the cell wall. (Bassil *et al.* 2004). B contributes to metabolism activities of DNA, phenol metabolism, IAA, carbohydrates and proteins (Goldbach *et al.* 2001). Adiloglu and Adiloglu (2006) Found that the nitrogen, phosphorus, Manganese, zinc, iron, and Molybdenum concentrations in the ear leaf of maize, as well as magnesium, calcium, copper, Manganese, iron, zinc, and Molybdenum concentrations in the root of the maize crop, changed as a result of increasing boron concentration. Deficiency of boron greatly affects the quality and yield of most crops especially maize (Shabbir *et al.* 2020). Boron was considered the most suitable method for maize fertilization, and gives more monetary returns. Moreover, Boron achieved high yield and returns for maize crop (Kumar *et al.* 2019). The other nutrients found in the soil plants natural systems can be impacted by two crucial plant nutrients, potassium (K) and boron (B). They might make each other more abundant or less available to each other. One of the minerals that maize needs to finish its life cycle and increase yield as well as its component of maize crop are potassium and boron. (Rehim *et al.* 2018). Lakshman and Dawson (2022) showed that when potassium and boron were fertilized together rather than separately, the growth, yield, and characteristics were increased. Grain yield compared to the control increased to 65% with combined potassium and boron fertilization. For maize to increase the yield of crops, a combined treatment of 125 kg of (K) and 8 kg of (B) per ha is appropriate and beneficial. The highest of seed production of cowpea was 1.26 tons per hectare found with the application of (P) 60 kg/ha + (B) 2 kg/ha. Plant height, numbers/plant, yield components, chemical constituents and protein% of cowpea plants significantly increased when fertilization of potassium at 72 kg K_2O fed^{-1} compared with control and lowest levels of potassium (Zyada *et al.* 2020). So, this study aimed to assess the response of intercropping cowpea with maize to potassium fertilizer and boron foliar application on the productivity of both crops and monetary advantage.

MATERIALS AND METHODS

Description of Experimental Site

Field trials were conducted at Sers El-Layin Agriculture Research Station, Agricultural Research Center (ARC), (Lat. 30◦ 25 ′ 60 N; Long. 30◦ 58 ′ 0E), Minufiya Governorate, Egypt, during 2021 and 2022 summer seasons. Sugar beet/lupine and Egyptian clover were the previous crops in 1st and 2nd seasons, respectively. The soil was a clay. Physical and chemical analyses (average of the two seasons) of the soil were randomly taken from a depth 0-30 cm (Table 1) and were determined using the methods described by Jackson (1973).

Table 1. Soil properties of experimental soil before cultivation.

Mechanical properties		Chemical analysis	
Sand %	30.6	pH	8.10
Silt %	25.9	Available N (mg/kg)	39.19
Clay %	43.5	Available P (mg/kg)	16.44
Soil texture	Clay	Available K (mg/kg)	231.30

Research Design and Treatment Description

The experiment was laid out in a randomized complete block design (RCBD) conducted in split plot arranged in three replications. The main plot was three mineral potassium fertilizer levels (0, 30 and 60 kg/fed) for intercropping maize plants while solid maize (50 kg K/fed) potassium sulfate treatments (K_2O) were applied during soil preparation. Sub-plot factors included boron levels in three foliar applications of 17.4% boric acid (0, 350, and 700 g boron/fed). It was added twice beginning 45 and 60 days after planting of maize and cowpea. Monoculture maize and cowpea were used for calculating competitive relationships and yield advantages.

Agronomic Management

In this study, were used the maize cultivar (Yellow hybrid SC 168) and cowpea cultivar (Giza18). Maize seeds in sole and intercropping systems were planted on one side of the ridge at 80 cm, one plant/hill at spacing 25 cm apart with leave one plant/hill. In intercropping cowpea and maize sowing both crops on the same row with leave one plant/hill. Planting distance of sole cowpea was sowing on two sides of the ridge at 80 × 15 cm between ridges and hills, respectively with leave two plants/hill. In this study, plant densities of maize and cowpea were used in cropping system (100% maize: 50% cowpea). The plot area was 4.8 × 3 m^2, consisted of six ridges. Each ridge was three meters long and 80 cm wide. Maize and cowpea were planted on 23nd and 11th May in 2021 and 2022 seasons, respectively. In solid and intercropping cultures, two cuts of cowpea were taken at 60 and 105 days after planting in both seasons. The irrigation system used in this study was furrow irrigation. Calcium super phosphate (15.5% P_2O_5) at rate of 150 kg/fad was applied during soil preparation. While mineral N fertilizer as ammonium nitrate (33.5% N) was applied at rate of 120 kg N/fad which were added twice in equal doses, at 1st and 2nd irrigations under intercropping and sole cultures in both seasons. Other farming practices were carried out as recommended by the maize and cowpea.

Data collected

Each sub-plots middle row was used to gather data. Characteristics of maize included plant height (cm), ear length (cm), ear diameter (cm) number of kernels/row, number of rows/ear, ear weight (g), weight of 100-kernel (g) and grain yield (ardab/fed) after the grains' moisture was adjusted to 15.5%. Corresponding cowpea: fresh forage yield (ton/fed) was estimated.

Competitive relationships

1) Land equivalent ratio (LER):

$$LER = (Y_{mc} / Y_{mm}) + (Y_{cm} / Y_{cc})$$

where

Y_{mc} and Y_{cm} are intercrop yield of crop yields maize and cowpea. Y_{mm} and Y_{cc} are pure stand yield of crop a (maize) and b (cowpea) Willey (1979).

2) Aggressivity (A): It means to compare the amount of increase in LER a and b of the intercropping according to Mc-Gilchrist (1965), crop (a) on crop (b) with the anticipated crop to determine which crop had the highest yield.

$$A_{mc} = Y_{mc}/Y_{mm} \times Z_{mc} - Y_{cm}/Y_{cc} \times Z_{cm}$$

$$A_{cm} = Y_{cm}/Y_{cc} \times Z_{cm} - Y_{mc}/Y_{mm} \times Z_{mc}$$

Where

Y_{mm} and Y_{cc} = sole maize yield of m and sole cowpea yield c. Y_{mc} and Y_{cm} = intercropping yield of (maize) m and (cowpea) c. Z_{mc} and z_{cm} = when maize and cowpea are intercropped, their relative area ratios, respectively.

3) Land equivalent coefficient (LEC)

$$LEC = LM \times LC$$

where

LM = LER of maize and LC = LER of cowpea Adetiloye, *et al.* (1983).

Economic evaluation

1) **Monetary advantage index (MAI)** according to Willey (1979)

MAI = [(value of combined intercropping) × (LER – 1)]/LER.

2) **Gross revenue:**

Gross revenue = Price of maize yield + price of cowpea yield (LE)

For grain yield, maize cost 596 L.E. per ardab in Egyptian pounds, while for fresh forage of average two seasons, cowpea cost 463 L.E. per ton. (Bulletin of Agriculture Statistical Cost Production and Net Return, 2021).

Statistical Analysis

Analysis of variance was used in the statistical analysis by SAS program version, 9.2 (2009) software package. The collected data on maize and cowpea were subjected to proper static analysis of split- plot design. Treatment means were compared using LSD at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of potassium fertilizer levels under intercropping cowpea with maize on yield and its attributes of maize.

Data presented in Table 2 reveal that potassium fertilizer levels studied affected significantly these traits viz., no. of rows/ear, ear weight (g), weight of 100 kernels (g) and grain yield (Ardab/fed) of maize in the two growing seasons. The other studied traits plant height, ear length, ear diameter, no. of kernels/row did not differ significantly affected by potassium fertilizer under intercropping cowpea with maize in both seasons. The application of potassium fertilizer 60 kg/fed produced the highest plant height, ear length, ear diameter, no. of kernels/row, no. of rows/ear, ear weight and weight of 100- kernel compared with other levels under study in the two seasons. The application of potassium fertilizer 60 kg/fed gave the highest grain yield of maize (26.07 and 25.25 ardab/fed) compared to 30 kg/fed (25.01 and 24.23 ardab/fed) in the 1st and 2nd seasons, respectively. The lowest value in this respect was from the application of potassium fertilizer (unfertilized plants) 0 kg/fed (24.28 and 23.81 ardab /fed) in the first and second seasons, respectively. This increase may be due to potassium contributes to the activation of numerous physiological processes, which has an impact on photosynthesis and the movement of carbohydrates from leaves to roots, both of which can directly affect maize productivity. Additionally, this increase in yield and its components were influenced by increasing in the amount of potassium. These results are mostly similar to those found by Marschner, (2011), Xie *et al.* (2011), Aslam *et al.* (2014), Ouda *et al.* (2018) and Zyada *et al.* (2020).

Table 2. Effect of potassium fertilizer under intercropping cowpea with maize on yield and its attributes of maize in 2021 and 2022 seasons.

Treatment	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	No. of kernels/row	No. of rows/ ear	Ear weigh (g)	Weight of 100-kernel (g)	Grain yield (ardab/fed)
				Season 2021				
0 kg/fed	230.26	19.10	5.00	44.12	15.18	262.58	32.83	24.28
30 kg/fed	234.16	19.37	5.07	46.34	15.30	280.26	34.12	25.01
60 kg/fed	237.03	19.58	5.07	48.03	15.36	321.19	35.18	26.07
LSD (0.05)	NS	NS	NS	3.76	NS	25.25	1.40	1.24
Sole maize	229.21	18.93	4.90	47.27	15.47	300.47	35.05	25.44
				Season 2022				
0 kg/fed	227.27	18.24	4.73	43.93	14.69	259.11	32.56	23.81
30 kg/fed	231.78	18.49	4.87	45.80	14.72	269.56	34.53	24.23
60 kg/fed	233.72	18.88	4.90	47.13	14.84	296.67	34.80	25.25
LSD (0.05)	NS	NS	NS	1.06	NS	16.40	1.48	0.86
Sole maize	226.67	18.07	4.81	46.60	14.13	280.07	34.66	25.13

NS meaning; Not significant.

Effect of potassium fertilizer levels under intercropping cowpea with maize on fresh forage of cowpea.

Data from both seasons in Table 3 reveal that this trait reacted significantly to potassium fertilizer level studied. Fresh forage yield (ton/fed) was significantly increased with increasing amount of potassium fertilizers levels in the two seasons. The application of potassium fertilizer 60 kg/fed produced the highest fresh forage yield of cowpea (10.78 and 10.29 ton/fed) followed by 30 kg/fed (9.50 and 9.21 ton/fed) in the first and second seasons, respectively. On the other hand, the lowest value in this respect was from the application (unfertilized plants) 0 kg/fed (8.49 and 8.17 ton/fed) in the first and second seasons, respectively. This trend could be attributed to the potassium helps plants with several of metabolic processes, such as the production of certain enzymes, protein synthesis, and photosynthesis. It also plays an essential part in both production and development of crops. The results obtained are consistent with the data that was detected by Hawkesford *et al.* (2012), Raza *et al.* (2013), Ouda *et al.* (2018) and Zyada *et al.* (2020).

Table 3. Effect of potassium fertilizer and foliar application of boron under intercropping cowpea with maize on fresh forage yield of cowpea during 2021 and 2022 seasons.

Treatment	Fresh forage yield(ton/fed)	Fresh forage yield (ton/fed)
	2021	2022
Potassium fertilizer levels		
0 kg/fed	8.49	8.17
30 kg/fed	9.50	9.21
60 kg/fed	10.78	10.29
LSD (0.05)	0.90	0.89
Foliar application of boron levels		
0 g/fed	8.68	8.16
350 g/fed	9.71	9.30
700 g/fed	10.38	10.22
LSD (0.05)	1.09	1.42
Sole cowpea	17.88	17.02

Effect of foliar application of boron levels under intercropping cowpea with maize on yield and its attributes of maize.

The results presented in Table 4 show that the different levels of foliar application of boron affected significantly yield and its attributes of maize in the two seasons except for plant height in the 2nd season and no. of rows/ear in the 1st season and the 2nd season did not differ significantly affected by levels of foliar application of boron. The application of foliar application of boron 700 g/fed produced the highest plant height, ear length, ear diameter, no. of kernels/row, no. of rows/ear, ear weight and weight of 100-kernel compared with other levels under study in the two seasons. The application of foliar application of boron 700 g/fed gave the highest grain yield of maize (26.01 and 25.31 ardab/fed) compared to 350 g/fed (25.67 and 24.93 ardab/fed) in the first and second seasons, respectively. The lowest value in this respect was from the application of foliar application of boron 0 g/fed (23.68 and 23.05 ardab/fed) in the first and second seasons, respectively. This increase may be due to the structural role of boron in cell wall growth, division of cells, development of grains, and stimulation or inhibition of particular pathways of metabolism for sugar transport and hormone generation is considered to be among the most important functions of boron in plants. These results agree with those obtained by Brown *et al.* (2002), Ahmed *et al.* (2009), Shukla *et al.* (2015), Shabbir *et al.* (2020) and Lakshman and Dawson (2022).

Table 4. Effect of foliar application of boron under intercropping cowpea with maize on yield and its attributes of maize during 2021 and 2022 seasons.

Treatment	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	No. of kernels/row	No. of rows/ear	Ear weight (g)	Weight of 100-kernel (g)	Grain yield (ardab/fed)
Season 2021								
0 g/fed	225.53	18.87	4.96	44.15	15.04	269.27	32.97	23.68
350 g/fed	233.88	19.58	5.07	47.02	15.19	291.21	34.42	25.67
700 g/fed	242.03	19.60	5.12	47.33	15.60	303.54	34.73	26.01
LSD (0.05)	7.14	0.65	0.06	2.31	NS	16.24	1.12	0.66
Sole maize	229.21	18.93	4.90	47.27	15.47	300.47	35.05	25.44
Season 2022								
0 g/fed	227.66	17.48	4.70	43.18	14.53	259.77	32.98	23.05
350 g/fed	231.28	18.97	4.90	46.40	14.78	275.70	34.07	24.93
700 g/fed	233.83	19.16	4.90	47.29	14.93	289.78	34.82	25.31
LSD (0.05)	NS	0.80	0.11	2.05	NS	16.47	1.21	0.62
Sole maize	226.67	18.07	4.81	46.60	14.13	280.07	34.66	25.13

NS meaning; Not significant.

Effect of foliar application of boron levels under intercropping cowpea with maize on fresh forage yield of cowpea.

Data in Table 3 shows that this trait was reacted significantly to foliar application of boron levels studied. Fresh forage yield of cowpea increased by increasing boron up to 700 g/Fed. The application of foliar application of boron 700 g/fed recorded the highest fresh forage yield (10.38 and 10.22 ton/fed) followed by 350 g/fed (9.71 and 9.30 ton /fed) in 1st and 2nd seasons, respectively. Without spraying cowpea plants with foliar application of boron at 0 g/fed recorded lowest fresh forage yield (8.68 and 8.16 ton/fed) in the first and the second seasons, respectively. This might be due to the positive effect of boron on the yield components of cowpea. The function of boron is boosts plant stress tolerance, growth and grain yield. These results are in harmony with those found by Gupta, (1979), Goldbach *et al.* (2001), Cakmak, (2002), Adiloglu and Adiloglu (2006), Goldbach *et al.* (2007) Hussain *et al.* (2012) Rehim *et al.* (2018) and Kumar *et al.* (2019).

At the same time, the highest yield of maize was obtained from intercropped plots at 60 kg K_2O/fed with 700 g B/fed compared with sole cropping plots. The increase in yield of intercropped maize due to intercropping cereal with Legumes help to improve and keep soil fertility high, because cowpea helps in accumulating 15 kg N/fed. Cropping systems primary advantage is their increased ability to make efficient use of the land and other resources. As well as, higher yield compared with sole cropping maize. However, the highest fresh forage yield of cowpea was obtained from sole cropping plots compared with intercropped plots with maize. This is due to intensive shadowing hurting the production of cowpea intercropped with maize. These results are attributed to intercropping cowpea with maize improved the productivity of the unit land area more than the sole culture of maize and cowpea. These findings are in line with those presented by Hamd Alla *et al.* (2014).

Effect of the interaction between potassium fertilizer and foliar application of boron of maize intercropped with cowpea.

The results presented in Table 5 indicate that the interaction between potassium fertilizer and foliar application of boron did not demonstrate significant variations in any of the attributes except ear diameter and 100 maize kernels in weight in 2022 season only. The same results in this regard were noted by of Said and Hamd-Alla (2018).

Table 5. Effect of the interaction between potassium fertilizer and foliar application of boron under intercropping cowpea with maize on ear diameter and weight of 100 kernels in 2022 season for significant traits only.

Treatment	Ear diameter (cm)			Weight of 100 kernels (g)		
	0g/ fed	350 g/fed	700 g/fed	0g/ fed	350 g/fed	700 g/fed
	2022					
0 kg/fed	4.43	4.9	4.87	31.66	32.86	33.16
30 kg/fed	4.87	4.87	4.87	34.84	32.94	35.79
60 kg/fed	4.8	4.93	4.97	32.45	36.43	35.51
LSD (0.05)	0.18			2.10		

Competitive relationships and economic evaluation

The results shown in Table 6 indicate that land equivalent ratio (LER), Aggressivity (A), monetary advantage index (MAI) and gross revenue varied considerably throughout the two seasons combined due to the intercropping of maize and cowpea.

Land equivalent ratio (LER)

The results shown in Table 6 demonstrate that all land equivalent ratio values were greater than 1. Relative yield of maize RYM higher than the relative yield of cowpea RYC for all intercropping system. The highest LER was obtained at 60 kg K_2O/fed with 700 g B/fed (1.70) followed by at 60 kg K_2O/fed with 350 g boron/fed (1.65). This indicates that 70% (0.70 fed) more area would be required by a monoculture to equal the yield of cropping system. This illustrates yield advantages for the intercropped cowpea with maize compared to those obtained in monoculture. These results indicate that the land use efficiency of intercropping cowpea with maize is higher than that of sole cropping. The present trend was in general agreement with those obtained by Hamd alla *et al.* (2014), Said and Hamd-Alla (2018), Hamada and Hamd-Alla (2019), Ouda *et al.* (2018) and Hamd-Alla *et al.* (2020).

Aggressivity (A)

As shown in Table 6 the aggressivity reveal that the estimates the major crops maize were positive for intercropping system. While the second crop cowpea was negative. It means that major crop maize was the dominant crop as well as cowpea was dominated in this study. The aggressive behavior may be due to the taller major crop (maize) that shade on the short plants (cowpea). The same results were achieved by HamdAlla *et al.* (2014), El-Ghobashi *et al.* (2020) and El-Mehy *et al.* (2023).

Land equivalent coefficient (LEC)

The land equivalent coefficient was a measure of the interaction between intercropping system with the strength of the relationship. The expected productivity coefficient is required to be at least 25%. The yield advantage was achieved when the land equivalent coefficient value exceeds 0.25. land equivalent coefficient ranged from 0.37 -0.68 (Table 6). The advantage of the highest land equivalent coefficient 0.68 was obtained under 60 kg K_2O/fed with 700 g B/fed. While, the lowest value 0.35 was obtained 0 kg K_2O/fed with 0 g B/fed under intercropping cowpea with maize. With less interspecific competition for above-ground and underground environmental conditions when cowpea and maize were intercropped, both species produced higher economic yields per unit area than the other two. Results conform with Olubode, *et al.* (2015), Abdel-Wahab *et al.* (2016) and El-Ghobashi *et al.* (2018).

Table 6. Effect of potassium fertilizer and foliar application of boron under intercropping cowpea with maize on competitive relationships, monetary advantage index and gross revenue in combined of two seasons.

Treatment		Grain yield (ardab/fed)	Fresh forage yield (ton/fed)	LER values		Total LER	A_M	A_C	LEC	MAI L.E. fed^{-1}	Gross revenue L.E. fed^{-1}
Potassium fertilizer levels	Foliar application of boron levels			RYM	RYC						
0 kg/fed	0 g/fed	22.72	7.15	0.90	0.41	1.31	0.46	-0.46	0.37	3986.52	16846.28
	350 g/fed	24.45	8.58	0.97	0.49	1.46	0.48	-0.48	0.48	5842.86	18544.74
	700 g/fed	24.97	9.29	0.99	0.53	1.52	0.48	-0.48	0.53	6561.95	19181.08
30 kg/fed	0 g/fed	23.07	8.50	0.91	0.49	1.40	0.45	-0.45	0.44	5051.41	17679.93
	350 g/fed	25.37	9.21	1.00	0.53	1.53	0.49	-0.49	0.53	6714.18	19382.44
	700 g/fed	25.44	10.37	1.01	0.59	1.60	0.47	-0.47	0.60	7485.21	19960.57
60 kg/fed	0 g/fed	24.32	9.61	0.96	0.55	1.51	0.46	-0.46	0.53	6397.35	18941.17
	350 g/fed	26.09	10.74	1.03	0.62	1.65	0.48	-0.48	0.63	8082.44	20516.97
	700 g/fed	26.59	11.26	1.05	0.65	1.70	0.49	-0.49	0.68	8672.18	21061.02
Sole maize		25.29	-								15070.00
Sole cowpea		-	17.45								8079.35

RYM = Relative yield of maize, RYC = Relative yield of cowpea.

Economic evaluation

Monetary advantage index (MAI)

The monetary advantage index is an indicator of the economic feasibility of cropping system. These values were positive due to intercropping cowpea with maize under the potassium fertilizer levels and foliar application of boron levels (Table 6). The highest monetary advantage index value (8672.18 L.E. fed^{-1}) was observed when fertilized at the level of 60 kg K_2O/fed with spray of 700 g B/fed. While, the lowest value 3986.52 was obtained at 0 kg K_2O/fed (unfertilized) with unsprayed boron/fed under intercropping cowpea with maize. According to these findings, intercropping cowpea and maize helped the growth and yield of the two crops (maize and cowpea). Especially, when fertilized at the level of 60 kg K_2O/fed with spray of 700 g B/fed. The present findings are well in agreement with that of Hamd Alla *et al.* (2014), Ahmed *et al.* (2019) and El-Mehy *et al.* (2023).

Gross revenue

Data presented in Table (6) show that increasing potassium fertilizer levels and foliar application of boron levels increased gross revenue. the gross revenue was increased in all treatments compared sole maize and sole cowpea. The highest gross revenue values were recorded when fertilized at the level of 60 kg K_2O/fed with spray of 700 g B/fed (21061 L.E. fed^{-1}) compared with sole maize (15070 L.E. fed^{-1}) and sole cowpea (8079 L.E. fed^{-1}). These results reveal that intercropping cowpea with maize is more profitable than sole maize and sole cowpea for Egyptian farmers. These results are by those observed by Singh and Ajeigbe, (2007), El-Ghobashi *et al.* (2018) Asiwe and Madimabe (2020) and Asiwe *et al.* (2021).

CONCLUSION

This study concluded that the application of Potassium 60 kg/fed + Boron 700 g/fed produced the highest yield and its components of maize as well as fresh forage of cowpea as compared to the other treatments. Competitive relationships and yield advantages revealed that all the treatments showed yield advantages compared with monoculture. Maximum values of land equivalent ratio, monetary advantage index and gross revenue were obtained when cowpea intercropped with maize with combined fertilization (60 kg/fed of K + 700 g/fed of B). Thus, applied at 60 Kg/fed of potassium and 700 g/fed of boron is considered appropriate and economical during intercropping of cowpea and maize to improve crop production and provide economic advantages for small farmers.

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استجابة تحميل لوبيا العلف مع الذرة الشامية للسماد البوتاسي والرش الورقي بالبورون على الإنتاجية لكلا المحصولين

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الملخص

أجريت تجربة حقلية بمحطة سرس الليان للبحوث الزراعية، مركز البحوث الزراعية، محافظة المنوفية، مصر، خلال موسمي ٢٠٢١ و٢٠٢٢. لتقييم استجابة تحميل لوبيا العلف مع الذرة الشامية لسماد البوتاسيوم والرش الورقي بالبورون على إنتاجية كلا المحصولين والمزايا النقدية. نفذت التجربة باستخدام تصميم القطاعات كاملة العشوائية بترتيب القطع المنشقة مرة واحدة بثلاث مكررات حيث تم وضع ثلاثة مستويات من سماد البوتاسيوم (٠، ٣٠ و٦٠ كجم للفدان) في القطع الرئيسية. بينما تم تخصيص القطع المنشقة لثلاث مستويات من الرش الورقي بالبورون (٠، ٣٥٠ و٧٠٠ جم للفدان). أوضحت هذه النتائج: أن إضافة ٦٠ كجم بوتاسيوم للفدان + الرش الورقي بـ ٧٠٠ جم بورون للفدان أعطت أقصى إنتاجية من المحصول ومكوناته من الذرة الشامية ومحصول العلف الأخضر من لوبيا العلف بالمقارنة مع المعاملات الأخرى. أظهرت العلاقات التنافسية ومزايا المحصول أن جميع المعاملات أظهرت مزايا إنتاجية أعلى مقارنة بالزراعة المنفردة. حيث تم الحصول على القيمة القصوى لمعدل كفاءة استغلال الأرض (١,٧٠) ومؤشر الميزة النقدية (٨٦٧٢ جنيهاً للفدان) وإجمالي الإيرادات (٢١٠٦١ جنيهاً للفدان) عند تحميل لوبيا العلف مع الذرة الشامية بالتسميد المشترك (٦٠ كجم بوتاسيوم للفدان + الرش الورقي ب ٧٠٠ جم بورون للفدان) مقارنة بإجمالي ايرادات الزراعة المنفردة للذرة الشامية ولوبيا العلف (١٥٠٧٠ و٨٠٧٩ جنيهاً للفدان) على التوالي. وبالتالي، فإن استخدام ٦٠ كجم من البوتاسيوم/فدان والرش الورقي بـ ٧٠٠ جم من البورون/فدان يعتبر مناسبًا واقتصاديًا لتحميل لوبيا العلف مع الذرة الشامية لتحسين إنتاجية المحاصيل وتوفير مزايا النقدية لصغار المزارعين.