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A Comparative Study Between Open-Pollinated and Maize Hybrids (*Zea mays* L.) Intercropped with Mungbean (*Vigna radiata* L. Wilczek) on Yield, Land Use Efficiency and Gross Monetary Value

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Abstract: The current work was conducted in order to investigate the effect of biological stress resulted from intercropping maize with mungbean on yield and yield components of the component intercrops and land use efficiency. Mungbean (*Vigna radiata* L. Wilczek) Kawmy-1 varietywas intercropped with maize (*Zea mays* L.) varieties viz. Single Hybrid-10 and Giza-2 (an open-pollinated variety) in a private farm in El Ayat, Giza governorate .Two ridges of both maize varieties were alternated with another or 4 ridges of Mungbean to form the intercropping patterns 2:2 and 2:4, respectively. Additional plots of maize solid plantings, solid I (the recommended practice,) and solid Il (the comparative treatment where the same plane density per hill under intercropping patterns vas applied' as the pure stand culture of mungbean. The obtained data showed that Mungbean plant height under intercropping patterns was taller than the pure stand plants. Mungbean number of pods seed yields per plant and per feddan were decreased due to the intercropping pattern Maize yield characters were increased by intercropping compared to the solid planting, e. nur of earsplant^{-1}, ear weight, grains weight e per ear and grain yield per plant. Grain yield per feddan under different intercropping patterns vas greater "hen Mungbean intercropped S Ingle Hybrid-10 than when it wags Intercropped with Giza-2. Generally, the best intercropping pattern in land use efficiency was 2:4 when Mungbean was intercropped with either, the Single Hybrid-10 (LER = 1.26 or with Giza-2 (LER = 1.20).

Key words: GMV · LER · Intercropping · Cropping patterns · *Zea mays* · Mungbean

INTRODUCTION

Due to the growing population all over the world, including in Egypt, the demand for different food products far exceeds the supply, creating a gap in food security [1]. On the other hand, farmland to produce different crops is becoming scarce day by day [2]. Thus, there is a growing need to maximize land use to accelerate productivity gains, which may encourage the rapid closing of the projected food security gap [3]. In terms of land use, intercropping, as a component of crop sustainability, is a more productive system of growing crops than growing them separately [2]. Intercropping of field crops is regarded as an essential practice when several economic field crops are competing for the same limited land area. Also, it is a common practice on small-scale farming system in the developing countries. Intercropping offers to farmers the opportunity to engage nature's principle of diversity at their farms. Spatial arrangements of plants, planting rates and maturity

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dates must be considered when planning intercrops. Dantata [4] in Nigeria, Eskandari [5] in Iran and Abd El-Lateef *et al.* [6, 7] in Egypt, it have been emphasized that intercropping is the most effective tool which permits higher grain yields and greater land use efficiency per unit land area. Mungbean has a wide range of compatibility with other crop species in intercropping systems such as guar [8], maize [9], sesame[10], sunflower [11] and sweetcorn [12]. Under the intercropping system, attention should be paid to the crops, which can grow with minimum competition and maximum profit [13]. Mungbean (*Vigna radiata* L. Wilczek) has been introduced to the Egyptian agriculture as a promising field crop [14]. It is a short duration legume crop with low water requirements [15], with high nutritive value and known in both southern parts of Asia and Africa for human consumption [16]. Mungbean as a summer crop will compete with other summer dominant crops in Egypt. When legume crops like mungbean grown as intercrop they suffer of biological stress due to shading form companion crop at different growth stages [17] and special attention in dealing with the biological stress when intercropping is practiced, short mungbean plants suffered much more from competition than the tall crop plants in a mixture leading to the reduction of photosynthetically active radiation (PAS) and in turn reducing the biological efficiencies of legume ability nutritional status [18]. Maize as a companion crop in most intercropping systems differ in their ability to depress the other dominated crop Therefore, the objective of this study is to investigate the effect of biological stress resulted from intercropping maize with mungbean on yield and yield components of the component intercrops and land use efficiency.

MATERIALS AND METHODS

Two field experiments were conducted during the two successive summer seasons 2020 and 2021 in a private farm Aiat proviance, Giza Governorate. The experiments aimed to study the effect of biological stress resulted from open pollenated and hybrid maize intercropping with mungbean on the growth, yield and land use efficiency. Maize (*Zea mays* L.) varieties viz. Single Hybrid-10and Giza-2 (an open-pollinated variety and mungbean (*Vigna radiata* L.Wilczek) variety Kawmy-1 were used. Mungbean was planted in solid cultures at the densities of 140 and 280 × 10^3 plants fed^{-1} while maize was planted as solid cultures at 23.3 and 46.6 × 10^3 plants fed^{-1} for solid I (The recommended practice) and solid II (The planting density under intercropping patterns); respectively. The planting densities of mungbean were equal to 100 and 150 % while for maize it represented 100 and 125 % of the solid cultures for solid I and solid II, respectively. Mungbean plants were intercropped with maize in three intercropping patterns by alternating 1, 2 and 2 ridges of maize with 3, 2 and 4 ridges of mungbean to form the intercropping patterns of 1:3, 2:2 and 2:4, respectively. These intercropping patterns provide 25, 50 and 33.3% of the cultivated area to maize and 75, 50 and 66.7% to mungbean for 1:3, 2:2 and 2:4 intercropping patterns, respectively. Thus, the experiment included 11 treatments arranged in a split-plot design with four replicates where maize varieties were arranged in the main plots and the cropping patterns in the sub-plots.

Table 1: The theoretical number of maize and mungbean plants under the different cropping patterns applied

Cropping pattern		Number of plantsfed^{-1} (× 10^3 plants)	
Maize	Mungbean	Maize	Mungbean
2	2	23.30	140
1	3	18.40	168
2	4	11.5	184
Maize Solid I Recommended		23.3	-
Maize Solid II(comparative)		46.6	-
Mungbean pure stand		-	280

The soil was ploughed twice, ridged and divided to experimental plots; a border of 1m was left between each two experimental plots to avoid shading effect ofmungbean seeds were grown in the assigned r ridgeson May 29th and June in the 2020 and 2021 seasons, respectively by the Hearty(wetted method) where the seeds were sown in hills 10 cm apart on both sides of the ridge. After the germination was completed. Mungbean seedlings were thinned at 2 plants per hill to obtain the required density for each pattern. The assigned ridges for maize were left, two weeks later Maize varieties were sown by the Afeer (dried method) in hills 30 cm apart and after complete germination, maize seedlings were thinned at 2 plants/hill except the solid I treatment where thinning was applied in I plant per hill. The theoretical umber OE maize and Mungbean plants under the different cropping pat terns are listed in (Table 1).

Mungbean plants were fertilized 60 kg N fed^{-1} while maize plants were fertilized with 90 kg Nfed^{-1}in two equal doges before the 1st and 2nd irrigations in the form of ammonium sulphate (20.6% N). The plants were left to grow till the time of harvesting, mungbean plants matured at 85 days from sowing. At maturity, ten plants were taken randomly from each experimental unit, then pod number and weight, 100-seeds weight and seed yield per plant were determined. Two ridges of each crop were devoted to determine seed yield per hectare. Maize yield characters *i.e.*, number of ears per plant number of rowsear^{-1}, number of grainsrow^{-1}, grain yield per plant, 100-grains weight and grain yield per feddan were determined. The land equivalent ratio for maize (L_z), mungbean (L_m) and the total land equivalent ratios ($L_z + L_m$) were estimated according to [19] as follows:

L_m = The intercropped yield of mungbean / pure stand yield of mungbean

L_z = The intercropped yield of maize / pure stand yield of maize

The obtained data were subjected to the proper statistical analysis according to [20]. Since the trends were similar in both seasons, the homogeneity test was carried out according to Bartlet's test and the combined analysis of the data was applied. Treatment means were compared using LSD test at 5% level.

RESULTS AND DISCUSSION

Effect of Cropping Pattern on Mungbean Yield Characters: Data presented in Table (2) show that there are no differences between maize varieties in their effect on mungbean plant height, number of pods per plant and the biological yield per feddan. However, seed yields per plant and per feddan were significantly affected due to the companion maize variety. Also, the pure stand culture treatment significantly exceeded the other intercropping patterns in number of pods, seed yield per plant and per feddan. Mungbean plant height under intercropping patterns is significantly taller than those cultivated in pure stand. Such increase in plant height expresses the adverse effect of the intraspecific competition between Mungbean plants and the associated maize plants. The greatest effect resulted from intercropping Giza-2 variety with mungbean in 2: 2 pattern. Meanwhile, increasing the ratio of mungbean in the intercropping pattern (as in the 2:4 pattern) decreased such competition. Several workers attributed the elongation of the intercropped plants to the competition for light [21-23]. Number of pods per plant was significantly reduced compared with the pure stand plants (Table 2). The greatest reduction was recorded when Giza-2 maize plants intercropped with Mungbean in 2: 2 pattern whereas the greatest number of pods per plant was recorded under 2:4 intercropping pattern with Single Hybrid -10 variety. Mungbean pod-set reduction under intercropping was reported by Subramanian and Rao [24]. Seed yield per plant of intercropped Mungbean was significantly reduced to various degrees according to the companion maize variety. When mungbean was intercropped with Single Hybrid-10, seed yield per plant was reduced by 44.6, 43.2 and 29.3 for the intercropping patterns 2:2, 1:3 and 2: 4, respectively compared to the pure stand treatment. The corresponding values for the intercropping Giza-2 variety were 52, 52 and 44.2 for the same intercropping patterns (Fig. 1). The obtained results indicate that the biological stress on mungbean plants under intercropping varies according to the companion maize variety and the intercropping pattern applied. Shen, (1984), attributed the reduction in the intercropped legume to the depression in the photosynthetically active radiation (PAR) that arrived to the intercropped plants. Also, Subramanian and Rao, (1988) reported a reduction in Mungbean seed yield from 82 to 15 gm per plant due to intercropping, they attributed such reduction to 'the decrease in number of pods Similar conclusion was reported by [24]. Fromthe same Table, no significant differences in the biological yield fed^{-1} were reported to the variety or intercropping pattern. Mungbean seed yield fed^{-1} was significantly decreased as compared with the pure stand treatment. As the number of the alternated rows with maize increased, seed yield fed^{-1} increased. Ingeneral, thereduction in seed yield fed^{-1} was expected due to the variation ratios of the cultivated area with Mungbean under intercropping patterns. Also, the reduction in pod-set and seed yield/plant shared in such yield depression (Fig. 2). The obtained results clearly show that the biological stress resulting from maize Single Hybrid -10 on the intercropped Mungbean was less than the variety Giza-2.

Effect of Cropping Pattern on Maize Yield Characteristics: Data presented in Table (3) clearly show that maize varieties differed significantly in yield characters. Single Hybrid-10 plants exceeded Giza-2 plants in number of earsplant^{-1}, grain yield plant^{-1} and grain yield fed^{-1}. Under intercropping patterns especially 2:4 pattern maize plants produced more number of ears per plant, with greater weights of both ears and grains as well as the greater weight of grains per plant compared with the comparative treatment (Solid 11). The beneficial effect of intercropping can be noticed from the increase in grain yield per plant by 43.8, 56.6 and, 85.5% when single hybrid-10 was intercropped with mungbean in 2:2, 1:3 and 2:4 patterns respectively in comparing comparison with the comparative treatment (Solid 11), (Fig. 3). The corresponding values for the same patterns when

Table 2: Effect of intercropping maize and mungbean on yield characteristics(Average of 2020 and 2021 seasons)

Maize variety	Intercropping system	Plant height (cm)	No. of podplant^{-1}	Seed yield plant^{-1} (g)	%	Biol. yield fed^{-1} (t)	Seed yield fed^{-1} (t)
Single hybrid- 10	2:2	81.3	16.6	4.03	55.4	3.50	0.403
	2:3	80.6	17.9	4.13	56.8	3.42	0.578
	2:4	77.0	21.2	5.14	70.7	3.50	0.771
	Mean	79.6	18.5	4.43	61.0	3.47	0.594
Giza-2	2:2	86.0	11.5	3.50	46.0	3.53	0.350
	2:3	79.6	14.9	3.50	49.0	3.50	0.490
	2:4	74.0	1$.1	4.06	55.8	3.41	0.609
	Mean)	80.5	13.8	3.69	50.6	3.48	0.483
	Pure stand	63.3	30.3	7, 27	100.0	4.08	1.353
	Mean	84.7	14.05	3.68	20.78	52	
Means	2:2	84.7	14.05	3.68	61.7	3.63	0.376
	2:3	80.1	16.16	3.82	52.4	2.46	0.534
	2:4	75.5	18.65	4.60	63.1	3.52	0.690
LSD at 0.05	Variety	NS	NS	0.6	-	N.S	0.163
	Cropping pattern	6.0	6.6	09	-	N.S	0.185
	Interaction	12.3	8.1	1.9	-	N.S	0.206

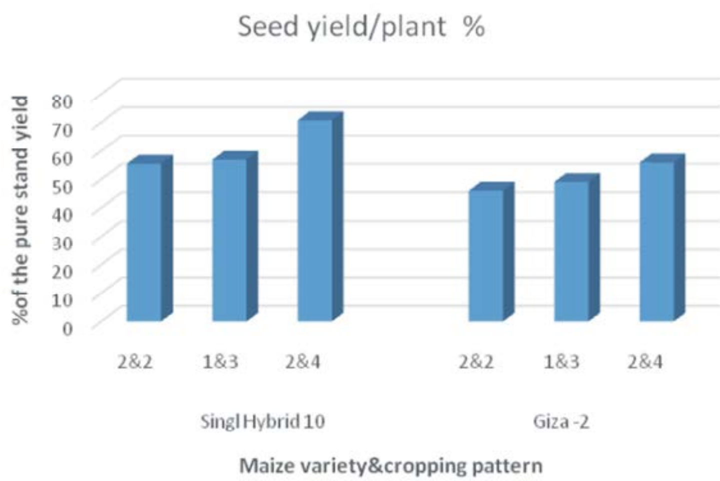

Fig. 1: Effect of maize biological stress on mungbean seed yield plant^{-1} (%) under different cropping patterns

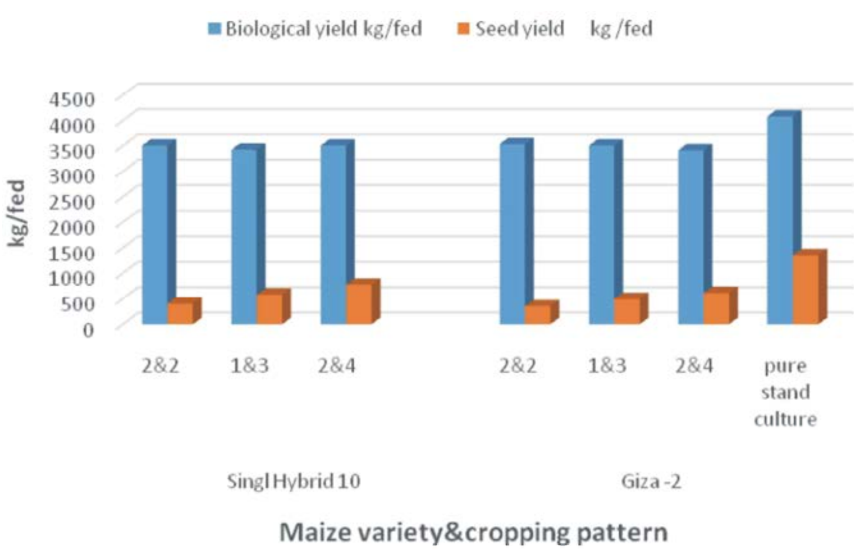

Fig. 2: Effect of maize biological stress on mungbean biological and seed yield fed^{-1} under different cropping patterns

Table 3: Effect of intercropping maize and mungbean on maize yield characteristics (Average of2020 and 2021 seasons)

Maize variety	Intercropping system	No. of ears plant^{-1}	Ear weight (g)	Grain weightear^{-1} (g)	Grain yield plant^{-1} (g)	Grain yield plant^{-1} %	Grain yield fed^{-1} (Ardab)
Single Hybrid-10	2:2	1.11	227	192.9	208.6	143.8	25.25
	2:3	1.13	236	210.1	227.1	156.6	24.32
	2:4	1.24	259	217.0	269.0	185.5	23.08
	Solid 1	1.12	204	171.0	228.0	157.2	33.23
	Solid II	0.97	173	147.0	145.0	100.0	29
	Mean	1.11	219.8	185.7	215.5	148.6	26.98
Giza-2	2:2	1.06	219	170.2	180.4	197.8	21.9
	2:3	1.10	226	180.0	198.0	217.1	19.8
	2:4	1.13	237	189.6	214.0	234.6	18.3
	Solid 1 (Recommended)	1.00	216	168.0	171.0	187.6	24.21
	Solid II (Comparative)	0.92	166	132.8	91.2	100.0	19.91
	Mean	1.04	212.8	168.1	170.9	187.4	20.78
Means	2:2	1.09	223	181.6	194.6	173.1	24.32
	2:3	1.12	231	190.5	215.6	196.9	23.08
	2:4	1.19	248	203.3	241.5	210.0	33.23
	Solid 1 (Recommended)	1.06	210	169.5	199.5	172.4	29
	Solid II (Comparative)	0.95	169.5	139.9	118.1	100.0	
LSD at 0.05	Varieties	0.06	NS	NS	26.1	-	3.01
	Cropping patterns	0.13	33.2	22.4	41.3	-	4.24
	Interaction	0.18	42.2	37.7	56.7	-	6.16

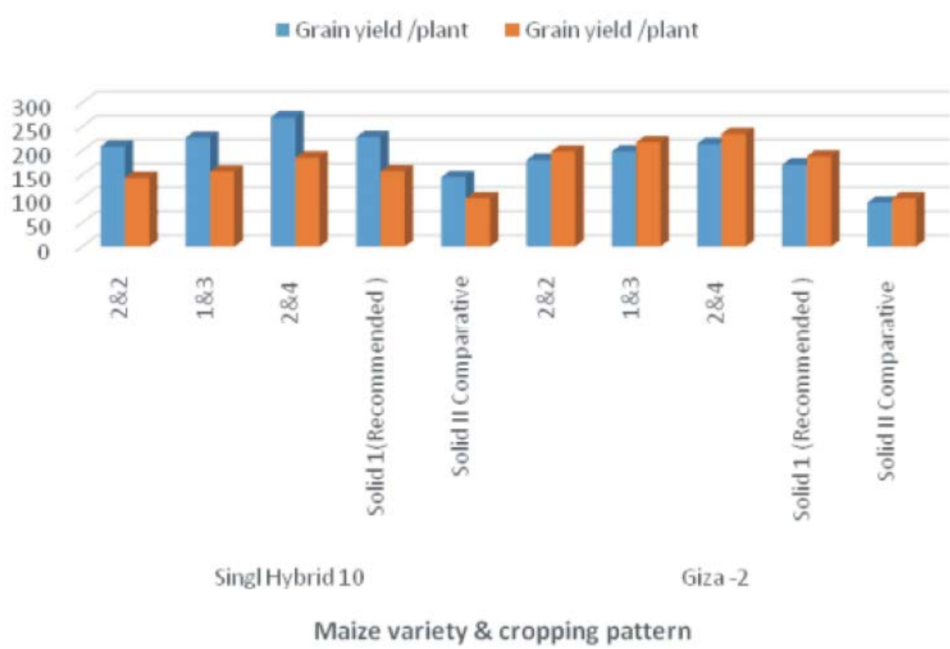

Fig. 3: Effect of maize intercropping with mungbean on grain yield plant^{-1} by (g) and (%) relative to solid II planting (the treatment adopted under intercropping in different cropping patterns

Giza-2 variety was used were 97.8, 117.1 and134.1%, respectively. The superiority of maize plants under intercropping could be attributed to the lower competition between maize and mungbean plants as well as the better illumination conditions resulted from the deeper spaces created by alternating tall canopy (maize) with a shorter canopy (mungbean), such conditions led to the superiority of maize productivity. Similar results were reported by using maize-soybean intercrops [25-27]. Also, Abd El-Lateef [21] came to a similar conclusion. Concerning grain yield per feddan the data clearly show that the solid recommended practice (Solid I) significantly

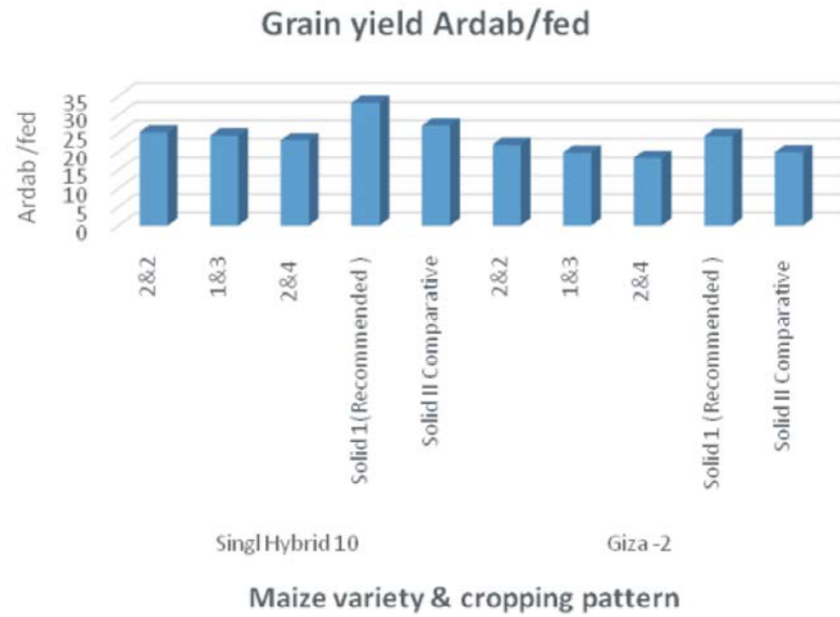

Fig. 4: Effect of maize intercropping with mungbean on grain yield (Ardab fed^{-1}) under different cropping patterns

Table 4: Effect of intercropping maize and mungbean on land equivalent ratios (LER) (Averages of 2020 and 2021 seasons)

Maize variety	Intercropping system	$L_{mung}(L_m)$	$L_{maize}(L_z)$	Total LER ($L_{Mung} + L_{maize}$)
Single Hybrid-10	2:2	0.3	0.75	1.05
	1:3	0.43	0.73	1.16
	2:4	0.57	0.69	1.26
Mean		0.43	0.72	1.15
Giza-2	2:2	0.26	0.89	1.15
	1:3	0.36	0.81	1.17
	2:4	0.45	0.75	1. 20
Mean		0.35	0.82	1.17
Means for Cropping patterns	2:4	0.28	0.82	1.10
	2:2	0.40	0.77	1.17
	2:3	0.51	0.72	1.23
LSD at 0.05	Varieties	0.05	0.07	NS
	Cropping patterns	0.11	0.08	0.06
	Interaction	0.14	0.13	0.13

Table 5: Effect of intercropping maize and mungbean on gross monetary value

aize Variety	Intercropping system	Maize GMV fed^{-1} (thousand LE)	Mungbean GMVfed^{-1} (thousand LE)
Single Hybrid -10	2:2	21.21	1.61
	2:3	20.43	2.31
	2:4	19.39	3.08
	Pure stand	27.91	-
Giza-2	2:2	18.40	1.4
	2:3	16.63	1.96
	2:4	15.37	2.44
	Pure stand	24.21	5. 41

exceeded the other cropping patterns in this criteria. Such superiority could be explained by the variation of the cultivated area with maize, where 50, 25 and 33.3% were only occupied by maize under intercropping patterns 2:2, 1:3 and 2:4 respectively. The obtained data of grain yield fed^{-1} show that the variety Single Hybrid-10 is better for intensive culture than Giz-2 variety (Fig. 4).

Land Equivalent Ratio (LER): Data presented in (Table 4) indicate that (LER) was greater than the unity (LER > 1) This result means that land-use efficiency under intercropping pattern was increased. Comparing the partial LER.. components, (L., Lz) it is clear that maize variety significantly affected either L_m and Lz components whereas the combined LER was not affected by the companion variety. Generally, the best intercropping pattern in land use efficiency was 2:4 when Mungbean was inter cropped with either, the Single Hybrid-10 (LER = 1.26 or with Giza-2(LER = 1.20).several investigators reported yield advantages from intercropping mungbean and cowpea with other crops [15, 26, 28].

Gross Monetary Value: Data presented in Table (5) indicate the profitability of different maize varieties and cropping patterns expressed as Gross Monetary Value (GMV fed^{-1} (LE). Generally, using maize Single Hybrid-10 in different intercropping patterns was more profitable than using open-pollinated variety (Giza-2). Increasing the ratio of maize in intercropping pattern increase the income due to maize and vice versa for Mungbean where intercropping pattern 2:2 gave the highest income from maize while the intercropping pattern 2:4 was more profitable for Mungbean than the other cropping patterns Similar results were reported by Gutu *et al*. [29].

It could be concluded that mungbean intercropping with maize can be applied successfully to increase the efficiency of land usage and gross monetary value.

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