Environment, Biodiversity & Soil Security

http://jenvbs.journals.ekb.eg/

Eco-friendly treatments for weed control in maize fields intercropped with cowpea

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TWO field experiments were conducted during summer seasons 2020 and 2021 to investigate the effect of integrated three weed control treatments (zero, once and twice hoeing) and intercropped cowpea with maize at three planting distances (10, 15 and 20 cm), on weed control, yield of maize and economic evaluation. A strip-plots design with three replicates was used. The results showed that hand hoeing once and twice caused reduction in dry weight of total weeds, and increased weed control efficiency (WCE), yield and yield components of maize and fresh forage yield/fed of cowpea. Highest values were with hand hoeing twice. Interplanting cowpea at 10 and 15 cm, increased percentage of WCE and fresh forage yield/fed of cowpea, irrespective of hand hoeing treatments, the opposite trend was observed with maize traits. Cowpea planted at 10 cm or 15 cm with applying hand hoeing twice significantly decreased the dry weight of total weeds at 45 and 60 days after planting and improved forage yield ton/fed of cowpea. Sole planting of both crops had the highest yields/fed. Nonetheless, intercropping cowpea + hand hoeing twice had yield and yield components at par with those of sole maize. The highest mean value of LER (1.51 and 1.48) was obtained by growing cowpea at 15 cm and twice time of hoeing. Weed control in maize with applied hand hoeing twice and planted cowpea at 15 cm recorded the highest values of gross and net return. The lowest yield of maize was obtained with zero hoeing and 10 cm planting distance. It could be concluded that application hand hoeing with growing cowpea as cover crop, at 15 cm planting distance was suggested for weed control, increased maize performance and net return for farmers, beside being eco-friendly.

Keywords: Intercropping, Hand hoeing, Planting distance, Weed control efficiency, Net return.

Introduction

Weeds (broad or narrow leaves) are one of the most serious constraints on crop production, specifically cereals. (Sharma et al., 2021). There are indirect losses owing to weeds draining nutrients, increased crop production costs, due to higher insect and disease incidence, and other agricultural processes. One of the output losses in various crops is attributable to weed infestation (Gharde et al., 2018). Weeds compete with crop for growth elements *i.e.*, water, nutrients, and light and thus reduce maize yield (Saudy, 2015). Maize (*Zea mays L.*) is the third-most significant cereal crop worldwide, following wheat and rice. The most major restriction on maize production, other than climatic changes, is weeds competing (Soltani et al., 2016). Widely spaced maize rows, which allow a large amount of ambient light through, cause weed competition.

In Egypt, hand hoeing and chemical methods for weed control are commonly used. However, mechanical method (hand hoeing) is constrained by some variables, such as labor and high cost, necessity of hoeing more than once during the growing season (Saudy et al., 2021). Chemical control is the most widely used method, however overuse of herbicides causes concerns related to the environment and health, as well as herbicide-resistant weeds, causing human health and ecological concerns (Van Bruggen et al., 2018). Appropriate weed management reduces costs and increase income for farmers besides being eco-friendly. Thus, there is a great demand for environmentally friendly approaches to weed management as alternatives to chemical weed control

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Received: 25/06/2023; Accepted: 20/07/2023
DOI: 10.21608/JENVBS.2023.219835.1222
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to maximize sustainability in agricultural production. The competitiveness of crops against weeds can be improved by using a cover crop, planting density, and hand hoeing.

In this regard, hand weeding is still an effective conventional weed control method, if done properly. Hoeing causes weeds to be ripped and/or uprooted, enabling crop plants to make great use of environmental resources, thus increasing their competitiveness against weeds (Adigun *et al*., 2020). Hoeing enhances the structure of the soil, drainage and aeration, as well nutrient availability for plants. (Thiem et al., 2020). Kumar et al. (2017) stated that hand hoeing produced least weed density and dry weight of all study weed species, followed by herbicide application. Adeyemi et al. (2020) noted that when weeding was done once, twice, and three times, the dry matter of weed significantly decreased by 77.6, 80.7, and 87.9%, respectively. Hoeing is a safe method of weed management in row crops that achieves excellent weed control efficacy (Abd El Lateef et al., 2021).

Intercropping is an alternative method to herbicides use for control of weeds (Sraw et al., 2016 and Singh et al 2017), intercropping decreases the development of late-emerging weeds because it enhances light interception by plants (Takim, 2012). The intercropping has intermediate values of weeds, while higher values were obtained in non-weeded plots and a lower value in two hoe-weeding plots, indicating that cowpea plants had, to a certain extent, control over weeds (Silva et al, 2009). Intercrops effectively control weeds better than sole crops due to the lower availability of environmental resources for weeds in intercropping systems (Pakeman et al., 2019, Rahimi et al., 2019 and Huss et al., 2022). Wider maize row spacing can be utilized to cultivate short duration legumes as intercrops such as cowpea, which will reduce the number of weeds by suppressing weed establishment and growth (Jamshidi et al., 2013 and Saudy et al., 2021). Where, an increase in crop density could lead to the enhancement of the collective shade of weeds by the crops which suppressed weeds growth. The intercrop plants had no influence on cash crop yield, but they considerably reduced weed biomass, by 42% relatively to a weeded control treatment, and 56% relative to a non-weeded control treatment (Verret et al., 2017). A strong negative relationship was obtained between plant densities and weed biomass, when weed biomass would reduce as plant density increased (Youngerman et al. 2018, El-Gedwy, 2019). Companion plants not only compete with weeds for environmental resources, but they may also compete with the crop. Therefore, plant density must be carefully chosen to outcompete weeds with reduce crops competition and yield loss (Verret et al., 2017). The goal of current study was to determine the optimum cowpea plant density intercropped with maize and weeding level to weed suppression, increase maize productivity and its economics.

1. Materials and Methods

A 2-year field study was conducted during summer seasons 2020 and 2021 at Sers El-Layian Agricultural Research Station, (30° 25` 60 N ; 30° 58` 0E), ARC, Minufiya Governorate, Egypt, to study the influence of integrate three weed control treatments and intercropped cowpea with maize at three planting distance on weed control, yield of maize and economic evaluation. Water was supplied by furrow irrigation system. The soil was a clay loam with 39.2% clay, 31.3 % silt, and 1.5 % course sand, 28.0 % fine sand. Chemical analysis of the soil (0 – 30 cm) are shown in table 1. Methods of soil analysis were applied according to Chapman and Pratt (1961).

Table 1: Soil chemical properties of Sers El-Layian region in 2020 and 2021 seasons.

Properties	2020	2021
pH	7.4	7.6
Ec (dS m^{-1})	1.06	1.07
Available N (mg kg^{-1})	38.57	39.10
Available P (mg kg^{-1})	15.85	16.20
Available K (mg kg^{-1})	229.51	230.46

The experiment design was randomized complete block design in strip-plots with three replicates. The weeding treatments were randomly assigned to the horizontal strips, cowpea planting distances were allotted in vertical strips. The sub-plot area was 10.5 square meter, with 5 ridges (3 m long and 70 cm wide). The experiment consisted of 9 eco-friendly treatments, which were combinations of 3 hoeing treatments (zero hoeing, once hoeing at 15 day and twice hoeing at 15 and 30 days) and 3 planting distances of cowpea sowing on the other side of maize ridge at 10, 15 and 20 cm apart, represent 120,000, 80,000 and 60,000 plants /fed, respectively. In addition to sole planting of maize and cowpea as recommended to calculate the competitive relationships.

Maize hybrid single cross 131 and cowpea (cv. Balady) were used in this study. Seeds were kindly provided by Field Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt. Maize and cowpea seeds were planted simultaneously on May 20th and 23th in 2020 and 2021 seasons, respectively. Maize was planted in one side of ridge (70 cm width) and thinned to one plant/hill spaced at 30 cm under intercropping and sole cultures. Cowpea seeds, inoculation with *Rhizobia japonicum*, were sown in the other side of maize ridge (two plant/hill spaced at 10, 15 and 20 cm) under intercropping culture, meanwhile sole cowpea was sowing in both sides of the ridge (two plant/hill spaced at 20 cm). In other words, the planting densities of intercropped cowpea with maize were equal to 100, 66.7 and 50% C: 100 M of sole cowpea and maize plant densities, respectively. Cowpea plants were cutting twice at 65 and 110 days after planting, meanwhile maize plants were harvested on September 7th and 11th in 2020 and 2021 seasons, respectively. The other agriculture practices for maize and cowpea crops were implemented in accordance with the Egyptian Ministry of Agriculture recommendations.

The previous crop was sugar beet which was harvested in May 1st in both seasons. Calcium super phosphate 85g p/kg at a rate of 150 kg/fed and potassium sulfate 400g k/kg at a rate of 50 kg/fed were added during soil preparation in the two summer seasons. Mineral N fertilizer of maize was added at the rate of 120 kg N/fed, of ammonium nitrate (33.5%N) in two equal splits doses. The first was added after thinning, whereas the second was added after two weeks later. Cowpea was fertilized with ammonium nitrate at rate of 20 kg N/fed at 20 days from cowpea sowing.

Data recorded

Weed assessment

Weeds were removed by placing 1 m^2 randomly from each sub-plot at 45 and 60 days after seeding (DAS) in both growing seasons for classified into broad-leaved weed and narrow-leaved weed, then weed samples were weighed fresh (g/m^2). After sun drying, the samples were placed in an oven at 70^0C until a constant weight to determine weed dry weight (g/m^2).

Weed Control Efficiency (WCE): It was calculated and expressed in percentage according to Mani *et al* (1973) as follows:

WCE (%) = (WDC – WDT)/ WDC x 100

Where, WDC=Weed dry weight in unweeded control plot, WDT=Weed dry weight in treated plot.

Maize

At harvest, randomly ten maize plants from each plot were chosen to determine plant height (cm), ear length (cm), ear diameter (cm), number of kernels/row, weight of kernels/ear and 100-kernel weight. Maize kernel yield/fed (ton) was estimated on the basis of experimental plot area by harvesting all plants of each sub-plot.

Cowpea

Cowpeas were harvested at 65 and 110 days after planting in both sole and intercropping systems. The green forage yield/fed was estimated at each cutting as the basis for the fresh forage yield/plot (kg), and the two fresh cuts were summed in tons/fed.

Competitive index:

Land equivalent ratio: LER was determined according to (Mead and Willey, 1980) as the following equation:

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

where: Y_{aa} is sole yield of crop a (maize), Y_{bb} is sole yield of crop b (cowpea), Y_{ab} is intercrop yield of a (when combined with b) and Y_{ba} yield of b (when combined with a).

Aggressivity (A): is index of how much one crop's relative yield gain exceeds that of the other in an intercropping system (Mc-Gilchrist 1965).and was computed as follows:

$A_{ab} = (Y_{ab}/Y_{aa}\ xZ_{ab}) – (Y_{ba}/Y_{bb} \times Z_{ba})$.

$A_{ba} = (Y_{ba}/Y_{bb} \times Z_{ba}) – (Y_{ab}/Y_{aa}\ xZ_{ab})$.

Where, Z_{ab} and Z_{ba} are the sown proportions of a & b, respectively.

Economic evaluation

Gross returns = kernel yield price of maize yield/fed + forage yield price of cowpea yield/fed

Total cost = fixed cost of maize + variable cost of cowpea (seeds price)

Net return = Gross returns − cost of treatment

The average prices and cost of maize were taken from the Bulletin of Agriculture (2020 and 2021), where price of one ton of maize was 3564 and 4164 L.E. While one ton of cowpea being 460 and 463 L.E. according farmer price in first and second season, respectively.

Statistical Manipulation

The variables that measured were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Duncan's Multiple Range (DMR) test was used at 5 % level of probability to compare differences between means (Waller and Duncan, 1969).

2. Results and Discussion

Weed Spread in sole and intercropped plots:

The weed survey undertaken in both seasons showed that weeds prevailing in the experimental site were: *Protulaca oleracea L.* (Purslane), *Corchorus olitorius* L. (Jews mallow), *Euphorbia geniculate* (L.) Link (spurge), *Xanthium Spinosum L.* (Cocklebur) and *Convolvulus arvensis* L. (Morning glory) as broad- leaved weeds. *Cyperus rotundus* L. (Nutsedge), *Echinochloa colonum* L. (Jungle rice) and *Cynodon dactylon* (L.) pers. (Bermuda grass) as narrow-leaved weeds.

3.1.1. Hoeing treatment effects on weed dry weight (g/m^2):

Results in Table (2) show that once or twice hoeing significantly suppressed the dry weights of both broad-leaved, narrow-leaved and total weeds g/m^2 at 45 days and 60 days from sowing in both seasons, compared to zero hoeing. Hand hoeing once and twice caused reduction in total weeds by 85.08 and 94.13% and 54.68 and 72.63 % after 45 days from sowing in 2020 and 2021 seasons, respectively, compared to the zero hoeing. Whereas total weeds decreased by 82.27 and 93.87 and 52.68 and 62.99% after 60 days from sowing. This result could be attributed to effectively control in weeds in the seedling stage by hoeing at 15 days after sowing, and repeat hoeing at 30 days after sowing significantly reduce weed development at subsequent growth stages. These results are in line with those obtained by Adeyemi et al. (2020) who reported that when weeding was done once, twice, and three times, the dry matter of weed significantly decreased by 77.6, 80.7, and 87.9%, respectively. Adigun et al (2020) who reported that weed biomass was reduced by 58% at two weeding in the early season and 70.7% in the late season compared to the zero-weeding treatment. Weed control efficiency (WCE) increased under hand weeding twice in comparison with hand weeding once, regardless of plant densities (Thiem et al., 2020). On contrary, the highest dry weed density of broad-leaved and narrow-leaved were obtained with zero hoeing treatment. The results are in accordance with the findings of Alhassan and Ukwetang (2022) no weeding treatment recorded the maximum weed dry weight at four, eight and twelve weeks after sowing (WAS) compared with other methods of weed control (hoe, chemical +hoe, chemical). Achan (2022) found that highest weed vigour and density per square meter of weeds in plot where a control (no weeding) was done than in plots treated with hand hoeing and herbicides.

Table (2) also shows that a reduction in weight of total weeds (WCE) in intercropping plots, which hoed once or twice time, was higher than sole maize in 2020 season. Whereas, WCE in sole maize (57.74 and 53.85%) was at par with those in intercropping plots that received once hoeing treatment (54.68 and 52.68%) at 45 and 60 days of sowing, respectively, in 2021 season. The inconstant trend of WCE in the sole and intercropping system, in the 2020 and 20201 seasons, may be attributed to variation in weed biomass between them. These results indicate~~d~~ that cowpea as an intercrop had great impact on weed suppression due to their ability to develop over-ground, which occupied the intra- and inter-row spaces in the intercropped treatments and restricted weed germination and growth. A similar finding was reported in a study of Rahimi et al. (2019) on WCE indicating the magnitude of effective reduction of weed dry weight by intercropping treatments over sole maize. The highest weed fresh biomass in sole maize than intercropping treatments could be as a result of free available spaces for the weed seeds for emergence (Pakeman et al., 2019).

3.1.2. Effect of cowpea planting distances on weed dry weight (g/m^2):

Results in Table (3) show that planting distance had significant influence on dry weight of broad-leaved, narrow-leaved and total weeds. Thus cowpea planted at a narrow distance of 10 and 15 cm recorded the lowest total dry weight of weeds compared with wider planting distance (20 cm) in the two growing seasons. The highest percentage of weed control efficiency (WCE) 28.98 and 53.49% was obtained by planting distance at 10 cm in 2020 season, and 32.91 and 16.49% by planting distance at 15 cm in 2021 season, at 45 and 60 days of sowing, respectively. Slight differences were noticed between the two planting spacing at 10 and 15 cm treatments, after 45 and 60 days from sowing, in the two growing seasons. These findings could be attributed to the higher density of cowpea plants, which limited light penetration to the weeds and increased competition for all nutrients, restricting weed development.

Table 2: Weed dry weight (g/m^2) as affected by hoeing level in growing summer seasons 2020 and 2021.

Hoeing treatments	Weed dry weight (g/m^2)							
	At 45 days from sowing date				At 60 days from sowing date			
	Broad-leaved weeds	Narrow-leaved weeds	Total weeds	Reduction% WCE	Broad-leaved weeds	Narrow-leaved weeds	Total weeds	Reduction% WCE
					2020 season			
Zero	87.22a	344.16a	431.38a	0.0	34.51a	602.00a	636.52a	0.0
Once	4.81b	59.54b	64.35b	85.08	6.92b	105.95b	112.88b	82.27
Twice	6.27b	19.05b	25.32c	94.13	5.00b	34.03c	39.02c	93.87
Sole maize$^+$	27.04	125.87	152.91	64.55	38.92	198.52	237.44	62.70
					2021 season			
Zero	39.48a	167.77a	207.26a	0.0	33.62a	245.26a	278.88a	0.0
Once	18.32b	75.60b	93.92b	54.68	15.32b	116.64b	131.96b	52.68
Twice	11.06c	45.63c	56.73c	72.63	13.13b	90.08c	103.22c	62.99
Sole maize$^+$	14.95	74.63	87.58	57.74	16.12	113.58	128.70	53.85

Sole maize$^+$ had twice hand hoeing application, Different letters in the same column indicate significant differences according to Duncan test at ($P \leq 0.05$).

Table 3: Weed dry weight (g/m^2) as affected by planting distance of cowpea in both seasons.

cowpea planting distance (cm)	Weed dry weight (g/m^2)							
	At 45 days from sowing date				At 60 days from sowing date			
	Broad-leaved weeds	Narrow-leaved weeds	Total weeds	Reduction% WCE	Broad-leaved weeds	Narrow-leaved weeds	Total weeds	Reduction% WCE
2020 season								
10	25.39b	123.53b	148.92b	28.98	12.38c	172.48b	184.86b	53.49
15	26.73b	135.69b	162.42b	22.55	14.64b	191.48b	206.12b	48.14
20	46.18a	163.52a	209.70a	0.0	19.41a	378.03a	397.44a	0.0
2021 season								
10	18.44b	91.57b	110.02b	25.84	17.09b	148.66b	165.75b	12.68
15	20.56b	78.95c	99.54b	32.91	17.31b	141.20b	158.51b	16.49
20	29.86a	118.48a	148.36a	0.0	27.68a	162.12a	189.81a	0.0

Different letters in the same column indicate significant differences according to Duncan test at ($P \leq 0.05$).

These results are similar to those obtained by Jamshidi et al. (2013) on weed infestation treatments which decreased as the densities of both the cowpea and maize were increased. Using wide plant spacing favored yield and its components of maize plants and fresh and dry weight of total weed (Youngerman et al., 2018, El-Gedwy, 2019). In addition, percent of WCE tended to increase with increasing plant density, irrespective of hand hoeing treatments. These results are in accordance with the findings of (Thiem et al., 2020).

3.1.3. Interaction effect between hoeing treatments and planting distance of cowpea on weed dry weight (g/m^2):

Results presented in Table (4) show that interaction between weed control treatments and cowpea planting distance was significantly different dry weight of total weeds, that cowpea planted at 10 cm or 15 cm with applying hand hoeing twice decreased the dry weight of total weeds at 45 and 60 days after planting.

Whereas, the highest dry weight of broad-leaved, narrow-leaved and total weeds obtained by wider spacing at 20 cm under zero hoeing level after 45 and 60 days from sowing in both seasons. It is noticeable that narrow planting distance had high cowpea planting density, which indicates that less light reached the soil and fewer weeds were stimulated to germinate. Hoeing treatments improved the control of maize weeds in narrow spacing as compared to wide spacing as reported by El-Gedwy (2019) corroborating the present results.

II. Maize traits

3.2.1. Hoeing treatments effects on Maize traits:

Plant height and yield components of maize were significantly influenced by hoeing treatments, except plant height and ear diameter in second season as shown in Table (5).

The tallest maize plants were obtained by hoeing treatments compared to zero hoeing level. However, this result was statistically on par with those that were weeded once or twice at a two week interval. Increased maize plant height could be attributed to the positive effect of hand hoeing treatments on reducing weed fresh and dry weights and decreasing inter-specific competition between maize and weed plants. These results are in harmony with those reported by Gashua (2017) weeding regime significantly influenced plant height with the tallest plants obtained where the crop was weeded three or twice times. El-Gedwy (2019) found that maize growth traits were increased as a result of using hand hoeing twice or some herbicidal treatments as nicosulfuron.

Hand hoeing treatments significantly increased yield components of maize compared to zero hoeing treatment in both seasons. The highest values of ear length, ear diameter, number of kernels/row, kernel weight/ear and 100-kernel weight produced by hand hoeing twice treatment, while un-weeded treatment gave the lowest one in the two growing seasons. Concomitant with the decrease in kernel weight per ear under un-weeded, kernel yield/ fed was decreased by 13.4 and 16.5% in first season and by 15.3 and 17.3% in second season compared to once and twice hoeing treatments, respectively. The maximum kernel yield/fed (3.64 and 3.81 ton) was obtained by hoeing twice in 2020 and 2021 seasons, respectively (Fig.1). Nonetheless, the differences between such superior treatment and once hoeing (3.51 and 3.72 ton/ fed) were not significant. The increment in maize yield and its components due to weed control indicate that weeds in the zero-hoeing plots competed with crop plants for light, water, space, and nutrients especially nitrogen. The results are in accordance with those reported by Thiem et al. (2020) hand weeding once and twice remarkably increased cob yield in comparison with no weeding; however, there was no significant difference in cob yield between hand weeding once and hand weeding twice. A similar finding was reported in the study of Achan (2022) who reported that the increase in grain yield of maize in hand hoeing could be attributed to the higher efficiency of weed control, allowing crop plants to make better use of environmental resources and improve crop competitiveness against weeds.

Table 4: Weed dry weight (g/m^2) as affected by interaction between hoeing level and planting distance of cowpea in both seasons.

Interaction effect		Weed dry weight (g/m^2)					
Hoeing treatment	planting distance (cm)	At 45 days from sowing date			At 60 days from sowing date		
		Broad-leaved weeds	Narrow-leaved weeds	Total weeds	Broad-leaved weeds	Narrow-leaved weeds	Total Weeds
2020 season							
Zero	**10**	65.92c	295.97c	361.89c	29.56a	412.23c	441.79c
	15	72.16b	336.50b	408.67b	31.01a	459.72b	490.74b
	20	123.58a	399.99a	523.57a	42.97a	934.06a	977.03a
Once	**10**	4.37e	57.29d	61.66d	2.92a	82.85e	85.78e
	15	3.78e	59.30d	63.07d	8.72a	77.44e	86.17e
	20	6.28de	62.03d	68.32d	9.13a	157.56d	166.69d
Twice	**10**	5.87de	17.34e	23.21ef	4.66a	22.36f	27.02f
	15	4.26e	11.27e	15.54f	4.19a	37.27f	41.45f
	20	8.68d	28.54e	37.22e	6.14a	42.47f	48.61f
2021 season							
Zero	**10**	31.16b	149.52b	180.68b	29.18a	246.84b	276.02b
	15	33.30b	123.31c	156.61c	29.93a	186.86c	216.80c
	20	53.99a	230.49a	284.49a	41.76a	302.08a	343.84a
Once	**10**	15.08cd	87.57d	102.65d	11.66a	77.90g	89.56g
	15	18.99c	52.96e	71.95e	11.00a	136.53d	147.53d
	20	20.89c	86.28d	107.17d	23.30a	135.49d	158.80d
Twice	**10**	9.08d	37.62f	46.73f	10.41a	121.26e	131.66e
	15	9.40d	60.59e	70.06e	11.00a	100.20f	111.20f
	20	14.71cd	38.68f	53.41f	18.00a	48.80h	66.80h

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

Table 5: Maize traits as affected by hoeing treatments in growing summer seasons 2020 and 2021.

Hoeing treatments	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	Kernels No./row	Kernel wt /ear (g)	100-kernel wt (g)
2020 season						
Zero	238.8b	20.07b	4.63b	41.13b	177.63c	33.58b
Once	254.2a	20.87a	4.89a	43.33a	198.86a	36.69a
Twice	256.5a	21.49a	4.98a	44.22a	204.38a	37.30a
Sole maize	251.2	21.47	4.80	44.03	193.50	37.56
2021 season						
Zero	245.1a	20.38b	4.69a	43.16b	182.09b	34.59c
Once	253.8a	21.80a	5.00a	46.04a	202.98a	36.60b
Twice	255.9a	22.10a	5.13a	46.89a	212.38a	37.97a
Sole maize	254.3	21.50	4.60	46.40	199.47	38.17

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

It is worth noting that, the yield and yield components of sole maize were higher than those traits of intercropped maize, which was unweed treatments, these results are in line with those obtained by Silva et al. (2009) who reported that although the cowpea had a certain control over weeds, they also competed with the maize plants and reducing yield of corn. Maize traits in sole planting gave the highest values, probably due to a reduction in solar radiation owing to increasing plant populations per unit area under intercropping (El-Mehy and Awad, 2022). Nonetheless, intercropping cowpea + hand hoeing treatment had yield and yield components at par with those of sole maize. Hoeing and cowpea as intercrop provided better plant growth conditions where nutrients were more available to these plants due to depressing the competition of weeds with maize compared to un-weeded.

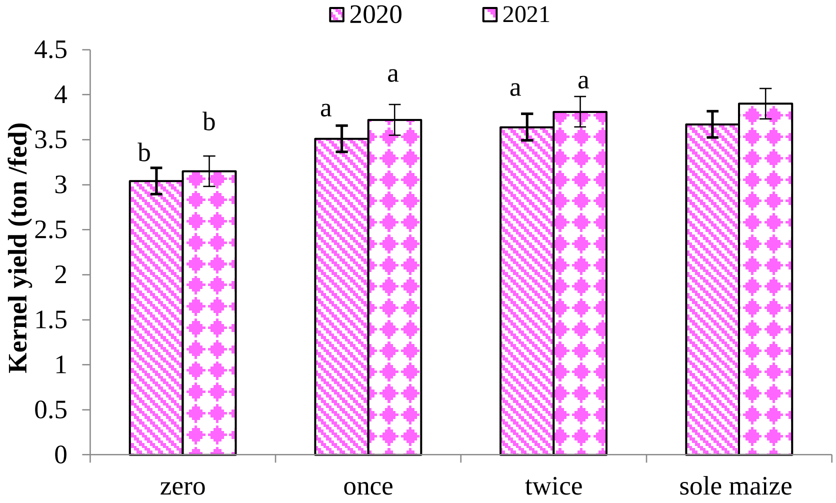

Fig. 1. Effect of hoeing treatments on kernel yield of maize (2020-2021).

Legumes as cover crop have the ability to increase crop yield possibly by supplying nitrogen through the nitrogen fixation process (Saudy et al., 2021). Jamshidi et al. (2013) stated that the use of cowpea as a cover crop increased maize productivity under both infested and devoid of weed conditions, while the minimum maize yield and the maximum weed mass were observed in the maize crop sown under weed-infested conditions.

3.2.2. Cowpea planting distance effects on maize traits:

Data in Table (6) show that plant height (in both seasons), ear length, ear diameter and 100-kernel weight (in season 2021) weren't significantly affected by cowpea planting distance. However, number of kernels per row as well as kernel weight per ear significantly affected by cowpea planting distance in the two growing seasons. Intercropped cowpea with maize at 20 cm planting distance produced the highest number of kernels per row and kernel weight per ear in 2020 and 2021 seasons, as shown in (Table 6). Increasing cowpea distance from 10 to 20 cm had significant effect on the maize yield in both seasons. Intercropping cowpea with maize at distance of 15 and 20 cm increased maize kernel yield by 7.89 % and 13.25% at the first season, 13.19 % and 14.72% in the second season compared with cowpea planted at distance of 10cm as shown in Fig 2. It is worth to noting that, there were insignificant differences in kernel yield/ fed when cowpea intercropped at 15 and 20 cm apart in the two growing seasons. Jamshidi et al (2013) stated that increasing cowpea density from 15 to 30 plants/m^2 had no significant effect on the maize yield loss though. Corn kernel yield did not differ, but weed biomass was 31% lower in plots with interseeded cover crops compared to plots without (Youngerman et al., 2018, Biruk et al., 2021).

Table 6: Maize traits as affected by planting distances of cowpea in both seasons.

cowpea planting distance (cm)	Plant height (cm)	Ear length (cm)	Ear diameter (cm)	Kernels No./row	Kernel wt /ear (g)	100-kernel wt (g)
2020 season						
10	250.8a	19.98b	4.70b	41.32b	185.85b	34.19c
15	248.7a	20.96a	4.86a	43.40a	193.86a	36.41b
20	250.0a	21.49a	4.94a	43.97a	201.16a	36.97a
2021 season						
10	254.1a	20.91a	4.79a	44.09b	188.63c	35.63a
15	250.2a	21.43a	4.99a	45.69a	200.49b	36.76a
20	250.4a	21.93a	5.04a	46.31a	208.32a	36.77a

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

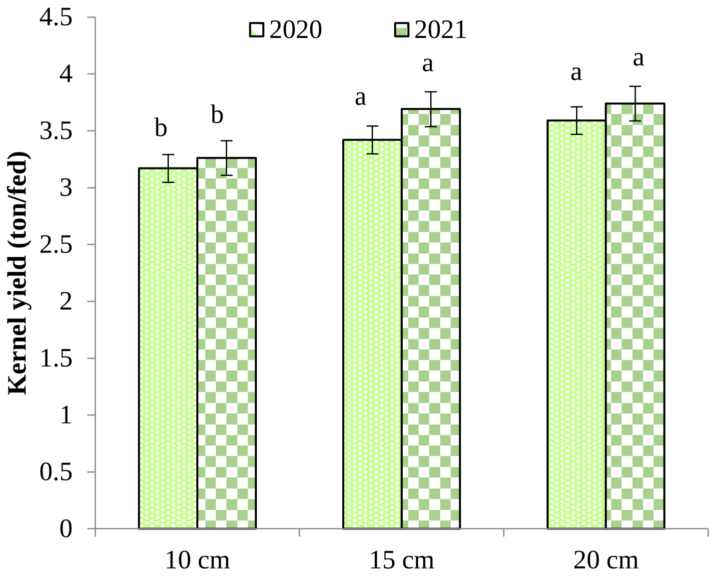

Fig. 2. Effect of cowpea planting distance on kernel yield of maize (2020-2021).

3.2.3 Interaction effect between hoeing treatments and cowpea planting distance on maize traits:

All studied characters of maize were not affected by the interaction between hoeing level and cowpea planting distance in both growing seasons, the data not shown.

III. Cowpea traits:

3.3.1. Effect of hoeing treatments on cowpea fresh yield:

As shown in Table (7) 1st, 2nd and total cuts of cowpea fresh yield fed^{-1} were significantly influenced by hand hoeing treatments in the two growing seasons. Weeding cowpea once and twice increased total fresh forage yield fed^{-1} by 34.8 and 39.7% in first season and 8.1 and 14.2% in second once compared to zero hoeing level, respectively. Nonetheless, differences between once and twice level failed to reach level of significance for fresh yield/fed. This result could be attributed to hand hoeing treatment significantly suppressed weed biomass/m^2 and reduce competition between cowpea and weeds on growth factors, i.e. nutrients, water and light. The significant reduction in cowpea yield when allowing weeds to compete cowpea plants could be attributed to inter-specific competition with the crop for nutrients, water, light and space which affected negatively the vegetative growth of plants especially plant leaf area and dry matter accumulation (Silva et al., 2009). These results are in line with that of Gashua et al. (2017) Cowpea yielded 2.7 t $^{1-}$ha and 2.8 t $^{1-}$ha in un-weeded plots as opposed to 3.7 t $^{1-}$ha and 3.8 t $^{1-}$ha in 2014 and 2015 from cowpea that was weeded three times at three-week intervals; however, the recommended weeding regime is twice for economic reasons as well as the fact that the results were statistically similar. Hoe weeding twice resulted in optimum growth and grain yield of cowpea (Adigun et al., 2020).

Table 7: Cowpea fresh yield (ton/fed) as affected by hoeing treatments in growing summer seasons 2020 and 2021.

Hoeing treatments	2020 season			2021 season		
	1st cut	2nd cut	Total cuts	1st cut	2nd cut	Total cuts
Zero	3.28b	1.46b	4.74b	4.16b	1.77b	5.93b
Once	3.96a	2.43a	6.39a	4.58a	1.83ab	6.41a
Twice	4.08a	2.54a	6.62a	4.84a	1.93a	6.77a
Sole cowpea	9.17	4.08	13.25	10.46	3.93	14.39

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

Adeyemi et al. (2020) stated that hoe weeding three produce the highest yield compared with other weeding treatments (no weeding, hoe weeding once, and hoe weeding twice).

As predicted, it was noted that the yield of fresh forage produced by sole cowpea was higher than that of the intercropping, irrespective the studied hoeing treatments. These results could be attributed to spatial arrangement of mixed cropping system increased interspecific competition between the intercrops for basic growth resources where efficiency of C4 crops for N and water use was higher than C3 crops. In addition, the increase in dry biomass production of sole cowpea may be explained by the absence of competition, which led to more dry matter accumulating in stems, branches, and leaves as a result of its good vegetative cover, which allowed it to harvest an adequate amount of sunlight for photosynthesis (Sibhatu, 2016). These results are in conformity with the findings of Saudy (2015) who reported that sole cropped gave higher dry biomass yield than the intercropped. Biruk et al. (2021) found that the highest yield of cowpea was obtained by sole cropping system. The reduction in intercropping sesame may be attributed to the aggressivity effects of maize (El-Mehy and Awad, 2022).

3.3.2. Effect of different cowpea planting distance on its fresh yield:

Cowpea fresh yield fed^{-1} was significantly influenced by different planting distance of cowpea, except 2nd cut in 2021 season (Table 8). Increasing the planting spacing of cowpea up to 20 cm significantly decreased fresh forage yield in both seasons. In addition, the highest total fresh forage yields 6.39 and 6.83 ton were obtained by intercropped cowpea with maize at 15 and 10 cm in 2020 and 2021 seasons, respectively. This is consistent with the findings of Atlaw (2017) who reported that the highest above ground dry biomass (10584kg ha^{-1}) and plant height (46.73 cm) of cowpea were recorded under narrow spacing (10 cm) compared to 20 cm spacing. Adigun et al. (2020) found that the use of row with narrow spacing resulted in significant limitation in dry weight weeds by 17–27% with subsequent more in cowpea growth and grain yield than wider row spacing.

Table 8: Cowpea fresh yield (ton/fed) as affected by planting distance of cowpea in both seasons.

Planting distance (cm)	2020 season			2021 season		
	1st cut	2nd cut	Total cuts	1st cut	2nd cut	Total cuts
10	3.89b	2.36a	6.25a	4.87a	1.96a	6.83a
15	4.22a	2.18a	6.39a	4.69a	1.78a	6.47a
20	3.21c	1.90b	5.11b	4.02b	1.80a	5.82b

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

3.3.3. Interaction between hoeing level and cowpea planting distance on yield of cowpea:

Fresh forage yield/fed of cowpea was not affected significantly by the interaction between hoeing treatments and cowpea planting distance in the two growing seasons, except first and total cuts in 2020 season. Results in Table 9 indicated that increase plant density of cowpea plants, by narrow distance at 10 and 15 cm, increased fresh forage yields of cowpea irrespective of hand hoeing treatments. In 2020 season, the highest first cut 4.53 ton fed^{-1} with once hoeing with growing cowpea at 15 cm, followed by 4.32 ton/ fed with hoed cowpea twice and planting cowpea at 10 cm. further, the highest total cuts 7.12 and 7.05 ton fed^{-1} were obtained by growing cowpea at 10 and 15 cm under twice and once hoeing treatments, respectively. This result indicated that yield of cowpea increased by reducing competition between weed and crops on environmental resources by hoeing and narrow spacing. A similar result was reported by Adigun et al. (2020) found that narrow spacing and two hoe weeding at 3 and 6 weeks after sowing improved weed control and productivity of cowpea.

Table 9. Interaction effect between hoeing treatments and cowpea planting distance on yield of cowpea in 2020 and 2021 seasons.

Interaction effect		2020 season			2021 season		
Hoeing treatments	Planting distance (cm)	1st cut	2nd cut	Total	1st cut	2nd cut	Total
Zero	**10**	3.11de	1.67a	4.78d	4.48a	1.84a	6.82a
	15	3.95bc	1.51a	5.46c	4.41a	1.73a	6.14a
	20	2.78e	1.20a	3.98e	3.59a	1.73a	5.33a
Once	**10**	4.24ab	2.61a	6.85a	4.97a	2.04a	7.02a
	15	4.53a	2.52a	7.05a	4.77a	1.77a	6.54a
	20	3.12de	2.18a	5.30c	4.00a	1.69a	5.69a
Twice	**10**	4.32ab	2.80a	7.12a	5.15a	2.01a	7.27a
	15	4.17ab	2.50a	6.67a	4.90a	1.83a	6.61a
	20	3.74c	2.33a	6.07b	4.48a	1.96a	6.44a

Different letters in the same column indicate significant differences according to Duncan test at (P≤0.05).

VI. Competitive index:

Results in Table (10) show that the mean land equivalent ratio (LER) values were always higher than 1.0. This indicated that utilization efficiency of land for maize-cowpea intercropping system was more advantageous than sole cropping. The highest mean value of LER 1.51 and 1.48 was achieved from the interaction between cowpea planted at 15 cm and twice of hoeing in 2020 and 2021 season, respectively. Which resulted in 51 and 48% greater land use than for either crop grown alone (Table 10). The lowest LER 1.08 and 1.20 produced by growing cowpea at 10 cm and no weeded treatment. This result could be due to high weed density at zero hoeing level, which increased competition between weeds and crops, and then reduce maize equivalent yield. A LER greater than 1.0 has been reported with cowpea/maize intercropping system by Shams and Lamlom (2020) and El-Shamy et al. (2022). This is consistent with the findings of Sibhatu (2016) who noting that the LER was significantly greater in the intercropping system than in both sole cropping practices. Concerning aggressivity, it estimated the difference in competitiveness of the intercropping components. Higher aggressivity numerical values show a greater difference in competitive ability of both crops. The positive sign indicates the dominant component and the negative sign indicates the dominated component. The results indicate that maize had positive sign, namely maize was dominant component, whereas cowpea plants were dominated component. The highest negative values were obtained by intercropping cowpea at 10 cm narrowest planting spacing, irrespective of weeding treatment. Similar results are accordance with Saudy (2015) they found that maize was the dominant crop, while cowpea was the dominated one. The aggressiveness value of intercropped maize was positive, showing that maize was the dominant component, whereas cowpea was dominated component (Shams and Lamlom, 2020).

Table 10. Interaction effect between hoeing treatments and cowpea planting distances on the Land Equivalent Ratio (LER) and Aggressivity (Ag) in both seasons.

Interaction effect		Maize yield ton /fed		Land equivalent ratio			Aggressivity		Land equivalent ratio			Aggressivity	
Hoeing treatments	Planting distance (cm)			L m	L c	LER	Ag m	Ag c	L m	L c	LER	Ag m	Ag c
		2020	2021	2020 season					2021 season				
Zero	10	2.64	2.85	0.72	0.36	1.08	0.72	-0.72	0.73	0.47	1.20	0.51	-0.51
	15	3.10	3.33	0.84	0.41	1.26	0.38	-0.38	0.85	0.43	1.28	0.36	-0.36
	20	3.35	3.27	0.91	0.30	1.21	0.46	-0.46	0.84	0.37	1.21	0.14	-0.14
Once	10	3.39	3.40	0.92	0.52	1.44	0.81	-0.81	0.87	0.49	1.36	0.77	-0.77
	15	3.44	3.83	0.94	0.53	1.47	0.23	-0.23	0.98	0.45	1.44	0.50	-0.50
	20	3.69	3.93	1.01	0.40	1.41	0.30	-0.30	1.01	0.40	1.40	0.31	-0.31
Twice	10	3.48	3.51	0.95	0.54	1.49	0.82	-0.82	0.90	0.51	1.41	0.79	-0.79
	15	3.71	3.99	1.01	0.50	1.51	0.43	-0.43	1.02	0.46	1.48	0.56	-0.56
	20	3.73	3.91	1.02	0.46	1.47	0.14	-0.14	1.00	0.45	1.45	0.15	-0.15
Sole maize		3.67	3.90	1	-	1	-	-	1	-	1	-	-

VII. Economic evaluation:

The economic analysis showed that the intercropped cowpea with maize at 15 and/ or 20 cm planting distance and hoed twice had the highest gross return for maize and intercropping (Table 11). Twice hoeing with intercropped cowpea at 10 cm had the highest gross return of cowpea and total cost of the intercropping. However, weed control in maize with applied hand hoeing twice and planted cowpea at 15 cm recorded higher values (5215 and 6545 L.E/fed) for net return in first and second season, respectively. However, the lowest net return was obtained with zero hoeing treatment along with the narrowest cowpea planting distance (10 cm). Except for the zero weed control practices and 10 cm planting distance, the other intercropping combination recorded higher values of net return comparing to sole maize. A similar finding was reported in the study of Saudy et al. (2021) who found that hoeing achieved the highest gross and net returns, followed by cowpea intercropped with maize, comparing to herbicide, rice straw mulch and sorghum extract. Intercropping maize had more economic advantages than growing it alone, maize with cowpea (Shams and Lamlom, 2020), with soybean (Abd-Rabboh and Koriem, 2022), and sesame (El-Mehy and Awad, 2022).

Table 11. Interaction effect between hoeing treatments and cowpea planting distances on economic evaluation in both seasons.

Interaction effect		Gross return (L.E/fed)			Total Cost	Net return	Gross return (L.E/fed)			Total Cost	Net return
Hoeing treatments	Planting distance (cm)	Maize	Cowpea	total			Maize	Cowpea	Total		
		2020 season					2021 season				
Zero	10	9409	2199	11608	10310	1298	11867	3158	15025	12234	2791
	15	11048	2512	13560	10185	3375	13866	2843	16709	12084	4625
	20	11939	1831	13770	10060	3710	13616	2468	16084	11934	4150
Once	10	12082	3151	15233	10755	4478	14158	3250	17408	12757	4651
	15	12260	3243	15503	10630	4873	15948	3028	18976	12607	6369
	20	13151	2438	15589	10505	5084	16365	2634	18999	12457	6542
Twice	10	12403	3275	15678	11200	4478	14616	3366	17982	13279	4703
	15	13222	3068	16290	11075	5215	16614	3060	19674	13129	6545
	20	13294	2792	16086	10950	5136	16281	2982	19263	12979	6284
Sole planting		13080	6089	13080	10700	2380	16240	6145	16240	12679	3561

3. Conclusion

Egyptian farmer used to hoe maize not just to remove weeds, but also to stimulate maize plants to produce supporting roots. It is possible to increase its efficiency in controlling weeds by integrate with growing cowpea as a cover crop to reduce the spread of weeds (as an environmentally friendly method). In regards to this, the current study showed that combination of hand hoeing twice and growing cowpea with maize at 15 cm plant distance can be suggested in maize agriculture as a safe and environmentally acceptable weed management approach and improved maize performance. In addition, Cowpea as a legume crop, increased soil fertility, LER and net return as well as produce additionally fodder production.

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