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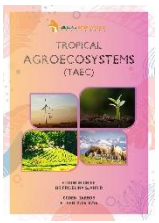

RESEARCH ARTICLE

IMPACT OF AZOLLA WITH DIFFERENT FERTILIZER RATES ON VEGETATIVE GROWTH, YIELD, QUALITY AND ECONOMIC EVALUATION IN ZUCCHINI

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ABSTRACT

The challenge of reducing the greenhouse gas emissions (GHGs) for preserving the environment and increase the food production is one of the main challenges in the agricultural sector to face climate change impact. This challenge encourages the world for maximaizing the mineral fertilizers' efficiency with the less utilized amount. This paper aims to evalualte the efficacy of Azolla on vegetative growth, fruit quality, yield and storability in zucchini with utilizing different rates of mineral fertilizers. The experiment was carried out in the experimental farm of Dokki site for Protected Agriculture, Ministry of Agriculture and Land Reclamation, Giza, Egypt, during two successive seasons of 2022 and 2023. Three different treatments of mineral fertilizers were applied on zucchini **(***Cucurbita pepo***)**, which represented 100, 75 and 50% of the recommended dose of NPK. The applied fertilizer treatments were represented once with Azolla (soil addition at rate 5g/plant) and once without. The best vegetative and fruit properties, nutritional status of plants and yield of Zucchini were revealed by the recommended dose of mineral fertilizers (100%). The treated soil with Azolla indicated significant higher measurements such as growth, NPK content of plants, yield and properties of zucchini fruits compared with the untreated soil plants. The highest yield was recorded with the recommended mineral fertilizer dose and the treated soil with Azolla. The less mineral fertilizer treatment (75% of the recommended dose) with the treated soil of Azolla had achieved higher nutrient content, physical and chemical properties than using the recommended dose of mineral fertilizer without Azolla, however the recommended dose of mineral fertilizer without Azolla showed higher yield and fruit quality higher the 75% mineral fertilizers with adding Azolla. The highest nutrient use efficiency was performed with Azolla treatment and 50% of mineral fertilizer. The highest revenue and net profit appeared by 100% mineral fertilizers with adding Azolla, but with low to insignificant difference between the same fertilization dose with non-Azolla addition. While 75% mineral fertilizers with adding Azolla showed a high revenue and net profit with a significant difference (close to double) between the same fertilization dose with non-Azolla addition.

KEYWORDS

Zucchini , Azolla, Fertilizer rates, Nutrient use efficiency

1. INTRODUCTION

The Egyptian government has adopted the project of 100,000 greenhouses, as a means of using modern technologies and patterns in agriculture with the aim of increasing production and achieving a large economic return, while at the same time increasing the efficiency of the land and water units. In an attempt to replace vegetables produced in greenhouses with their open counterparts to raise self-sufficiency rates of strategic crops (Tolba, 2017). The zucchini (Cucurbita pepo) is a popular vegetable and one of the main vegetable crops in Egypt and other countries of the Mediterranean region as well. The total cultivated area in Egypt was 59340 acres (acre = 0.42 hectare), produced about 455866 tons on annual basis with an average of 7.682 tons/acre (MALR, 2017). Zucchini is mainly cultivated during spring and autumn seasons, but could be also cultivated in summer season. Zucchini is characterized by rich bioactive and nutrients compounds such as phenolics, flavonoids, vitamins, amino acids, carbohydrates and minerals (especially K). Zucchini contains low energy content (about 17 Kcal/100 g of fresh pumpkin) and large amount of fiber (Tamer et al., 2010).

The agriculture, forestry, and other land use (AFOLU) sector shared with 14.9% (48,390 Gg CO_2e) of national GHG emissions in 2015. The GHG emissions from the utilization of chemical fertilizers had the largest share of total GHG emissions 66% followed by livestock 34% (Egypt's first Biennial Update Report, 2018). N_2O is an essential GHG that participates to climate change, according to its long atmospheric lifetime (over 100 years) and is about 300 times better at trapping heat than CO_2. Therefore, even small emissions of N_2O affect the climate (Farag and Abd-Elrahman, 2016). However the importance of nitrogen fertilizers to enhance the crop growth and increase the yield, but the persistent utilization of mineral fertilizers have a negative impact on soil organic matter reserves. The excessive utilization of mineral fertilizers could lead to further deficiency in Nitrogen (Hossain et al., 2001), acidification of the soils significantly reduce of soil microbial activity in long run and reverse impact on soil fertility, soil productivity and environmental safety on the long run (Mahdi et al., 2010; Yadav et al., 2014; Sutton et al., 1991; Stumpe and Vlek, 1991). The plants do not absorb all the annual applied mineral fertilizers to the soil. The mineral fertilizers are also forfeited rapidly by leaching in drainage water in the soil or volatilizing in the atmosphere that

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cause rise of greenhouse gases, pollution of groundwater and salinization of soil (Hernández et al., 2010; Simpson et al., 2011). Consequently, the best management of mineral fertilizer utilization of crops will contribute with saving money to farmers by improving nutrient use efficiency, and save the environment by reducing GHG emissions (Farag and Abd-Elrahman, 2016).

Azolla is a free floating freshwater fern that grows rapidly, which doubles its biomass in 3-5 days. Azolla falls down the pteridophyte division and has the ability to fix atmospheric nitrogen by forming a symbiotic association with the Blue-Green Algae, Anabaena azollae (Bhubaneswari and Kumar, 2013). The symbiont releases a rich amount of ammonia (biologically fixed nitrogen), where this ammonia is absorbed by the host through branched hairs exist in the cavity and unbranched hairs for transmitting fixed carbon from host to the Cyanobiont (Peters et al., 1980). Azolla is characterized by its bilobed leaf with a dorsal and ventral lobe. The dorsal lobe has the green or purple colour with a central cavity that houses the symbiotic Anabaena azollae. The ventral lobe is relatively thin and mainly stays partially immersed in water and provides buoyancy (Raja et al., 2012). The optimal target crop for applying Azolla is lowland rice on account of the similarity of their reuired environmental conditions, where areas with plenty of water such as swamps, streams, lakes and other small water bodies are the suitable environment of Azolla. Therefore, the flodded habitat of lowland rice is a suitable environment for Azolla to grow in. The global species of Azolla are: A. pinnata, A. filiculoides, A. rubra, A. microphylla, A. imbricate and A. caroliniana and all these contain the Anabaena association (Giller 2001; Raja et al., 2012).

The utilization of biological fertilizers would be a necessity for increasing the crop productivity and improving the soil fertility on the long term. The Azolla fern is one of the biological fertilizers that contributes with the soil fertility enhancement. Alzolla composed an economical and ecofriendly biofertilizer that supplies the soil carbon and nitrogen enrichment and overall improving the soil/crop management practices and fertility status (Kaushik and Prasanna, 1989).

The present research aims to study the impact of Azolla fern on production, quality and storability of Squash fruits with different rates of mineral fertilizer. The reduction of mineral fertilizer utilization will reduce the production costs and will preserve the environment and the human's health.

2. Materials and Methods

The experiment was carried out at the experimental land in Dokki site for Protected Agriculture, Ministry of Agriculture and Land Reclamation, Giza, Egypt, on Seeds of zucchini (Cucurbita pepo var. Rossina, cv. Hybrid F1) during two successive seasons of 2022 & 2023, under a greenhouse of white nets (30 m length and 8.5 m width).

2.1 Plant Material

Seeds of zucchini (Cucurbita pepo var. Rossina, cv. Hybrid F1) were sown on 26th and 24th June 2022 and 2023 in field at the first and second seasons, respectively. The physical and chemical properties of the experimental soil are tabulated in Table 1.

Table 1: Analyses of the Experimental Soil

Clay %	Silt %	Sand %	Texture	pH	EC dS/m	Cations meq/l				Anions meq/l		
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	$SO_4^=$
48.2	42.3	8.5	Clay silt	8.25	1.26	2.80	1.55	6.34	1.18	2.44	5.46	3.58

2.2 Chemical Composition of Azolla

The chemical composition of Azolla (Table 2) as reported by various researchers.

Table 2 : The Chemical Composition of Azolla.

Nutrient	% of dry matter
Protein	**24**
Fibre	**9.1**
Ash	**12**
N	**5**
P	**0.9**
K	**4.5**

2.3 Experimental Design

The layout of the experiment was divided into ridges (90 cm width). The seeds were sown at a space of 50 cm in double rows on the ridge. The experiments were arranged in split plot design with three replicates. Three mineral fertilizer rates were applied, which are 100, 75 and 50% of the recommended dose for NPK to the Ministry of Agriculture in the main plots. Two treatments of Azolla (with and without Azolla) were randomized in the sub plots for each mineral fertilizer treatment. The plot area was 4.5 m^2 (5 m length and 0.9 m width). The recommended mineral fertilizer of NPK was at the rate of 22 kg N, 9 kg P_2O_5 and 25 kg K_2O/1000 m^2 according to (Shehata et al., 2016). These fertilizers were provided using a multi fertilizer (20:9:20) at rate 125 g/m^2. The fertilizer was injected by drip irrigation system twice per week. Azolla was applied with soil addition at rate 5g/plant before sowing the seeds. Other agricultural practices were done as recommendations of Ministry of Agriculture.

2.4 Data Recorded

All the recorded data were taken at the two studied seasons at the same time.

2.4.1 Growth and Nutrient Measurements

The growth and nutrient measurements are taken weekly, starting from the age 45 days (from sowing). Five samples from each plot are chosen randomly. The recorded growth measurements are plant height, leaf number, stem diameter and shoot fresh weight of plant. The recorded nutrient measurements are chlorophyll, NPK in plant, total nitrogen, phosphrous and potassium. Chlorophyll reading was measured at the fourth upper leaf of the plant sample using Minolta Chlorophyll Meter Spad 501. Nutrient content (NPK) in zucchini plants were also determined at the fourth upper leaf, according to the procedure described by (FAO, 2008). Total nitrogen was measured by Kjeldahl method, while phosphorus was defined using Spectrophotometer and potassium was determined photo-metrically using Flame photometer.

2.4.2 Yield Measurements

The yield measurements are taken biweekly, where the zucchini fruits were harvested twice a week starting from the age 50 days (from sowing). The yield measurements included total yield, Fruit no/plant, fruit quality and storage. The yield were collected and recorded per plot after each harvesting day. The recorded weight of yield is accumulated till the end of the planting period. Five plants from each replicate were randomly chosen to measure number of fruits per plant. The fruit quality parameters are fruit weight, fruit length, fruit diameter, fruit firmness, total soluble solids and ascorbic acid content. The last parameters are measured from a random sample of 15 fruits from each replicate at harvest. The measured storage paramerters on the fruits of zucchini for each treatment are: a) Fruit firmness, which was measured by a hand pressure tester (Italian model) expressed in kg/cm^2; b) Total Soluble Solids percentage (TSS) that was determined by using refractometer according to A.O.A.C. (2000); and c) ascorbic acid content (mg /100 g fruit fresh weight), which was scaled by titration method using 2, 6 dichloro-phenole-endo-phenole (A.O.A.C., 2000).

2.5 Evaluation of nutrient use efficiency

Nutrient use efficiency (NUE) was calculated according to using the following equation (Jisha Chand, 2014):

$$\mathbf{NUE} = \frac{\mathbf{Yield\ (kg/m^2)}}{\mathbf{Nutrient\ applied\ (kg/m^2)}}$$

2.6 The Economic Evaluation

The economic evaluation relied on collected field data related to the crop budget for zucchini, in addition to secondary data published by the Economic Affairs Sector of the Ministry of Agriculture and Land Reclamation. Productivity and economic efficiency indicators were evaluated for each transaction and at each level per greenhouse. Productivity and economic indicators are estimated according to the following equations (Heady, 1968):

I. Total Revenue (TR) = productivity (Y) * price(P).

II. Net profit (NP) = Total Revenue (TR) - Total Costs (TC).

III. Gross Margin (GM) = Total Revenue (TR) - Variable Costs (TR-TVC).

IV. Relative profitability (RP) = Net Profit (NP) ÷ Gross Margin (GM).

V. Profitability of Invested Pound (PIP) = Net profit (NP) ÷ Total Costs (TC)

2.7 Statistical Analysis

Data of the two seasons were arranged and statistically analyzed by the analysis of variances according to with SAS software, version 2004 (Snedecor and Cochran, 1980). Treatment means were compared by Duncan's test at significance level 0.05.

3. Results and Discussion

3.1 Vegetative Properties

The impact of the different mineral fertilizer rates on the vegerative growth parameters of zucchini plants, in addition to applying Azolla to the soil at the half of sub-plots for the seasons 2021 and 2022, are explained in Table 3. In both seasons, the higher the applied mineral fertilizer rate, the higher the vegetative growth paramerters values. The direct proportion between the applied mineral fertilizer rate (till 100%) and the values of vegetative growth paramerters could be explained by the role of mineral fertilizers several metabolic processes in plant, which contribute with promiting the growth (Marschner, 1995). The mineral fertilizer could enhance the activity of meristemic, which is essential to the metabolism of chlolophyll, amino acids, enzymes and protein synthesis (Salisbury and Ross, 1991). Furthermore, the fertilization motivates the plants to produce more number of leaves for stimulating the vegetative growth, so increasing N, P and K rates had an important role in enhancing the vegetative growth of zucchini plant (Jilani et al., 2009; Shedeed et al., 2014; Lasmini et al., 2015; Singh et al., 2015).

The injection of Azolla to the soil enhanced all vegetative parameters of plants compared to non-Azolla treatment. The positive impact of Azolla to vegetative growth could be returned to role of Azolla in cation uptake capacity that had a favorable impact on immobile plant nutrient uptake, which raise the plant growth (Hernandez et al., 2014). Moreover, Azolla had the nutients and microoranisms that increase the crop production. The utilization of composted organic materials as fertilizers can be a useful substitutional solution to inorganic fertilization in crop production for a sustainable agriculture (Amanullah and Khan, 2015)

Regarding the interaction between mineral fertilizer rates and Azolla addition, the highest values of all vegetative growth properties resulted from 100% of mineral fertilizer with adding Azolla. Treatment of 100% of mineral fertilizer with non-Azolla addition came in second order, followed by treatment 75% mineral fertilizer with adding Azolla. The lowest values of all vegetative growth properties resulted from 50% of mineral fertilizer without Azolla.

3.2 The Nutritional Content of Plants

The nutritional content (NPK) of zucchini plants that are shown in Table 4, explained the effect of the different mineral fertilizer rates, in addition to Azolla treatment, on N, P and K content of zucchini plants in the studied seasons. The recommended dose of mineral fertilizer (the highest rate) revealed the highest values of N, P and K content of plants followed by 75% mineral fertilizer, while the lowest N, P and K content obtained by the lowest mineral fertilizer rate (50%). Therefore, providing the adequate nutritional reuirements for plants leads to rising the nutrient content in the plant (Jilani et al., 2009; Eifediyi and Remison, 2010; Fiorentino and Fagnano, 2011; Feleafel et al., 2014). As well, the significant increasing of N, P and K content that appeared by Azolla treatments compare to the non-Azolla treatments, where Azolla could promote the soil physical and chemical properties, as well as nutrient uptake by plants (Hernández et al., 2014).

Table 3: Mineral Fertilizer Rates and Azolla Impact on Vegetative Growth Properties of Zucchini Plants in Both Seasons

Azolla treatment	2022 season								2023season							
	Fertilizer rate															
	100%		75%		50%		Mean		100%		75%		50%		Mean	
	Plant height (cm)															
Without	55.1	b	46.5	d	30.9	f	44.18	B	55.56	b	45.13	d	29.9	f	43.53	B
With	60.76	a	54.16	c	33.3	e	49.41	A	60.86	a	48.8	c	31.86	e	47.17	A
Mean	57.93	A	50.35	B	32.11	C			58.21	A	46.96	B	30.88	C		
	Leaf number/plant															
Without	33.8	b	29.9	d	21.5	f	28.39	B	35.8	b	30.4	d	22.7	f	29.94	B
With	34.53	a	30.8	c	22.1	e	29.14	A	36.73	a	33.86	c	23.53	e	31.06	A
Mean	34.16	A	30.36	B	21.83	C			36.26	A	32.16	B	23.13	C		
	Stem diameter (cm)															
Without	2.83	b	2.07	d	1.23	f	2.04	B	2.81	a	2.67	a	1.75	b	2.43	B
With	2.97	a	2.16	c	1.4	e	2.78	A	3.07	a	2.75	a	1.76	b	2.5	A
Mean	2.91	A	2.11	B	1.31	C			2.94	A	2.71	A	1.75	B		
	Chlorophyll (SPAD)															
Without	49.86	b	45.66	d	41.73	e	31.63	B	51.36	b	43.2	d	40.26	e	44.94	B
With	56.46	a	47.86	c	42.46	e	36.13	A	57.83	a	46.46	c	40.26	e	48.18	A
Mean	53.16	A	46.76	B	42.1	C			54.6	A	44.83	B	40.26	C		
	Shoot fresh weight (g)															
Without	3378.3	a	1792	c	916.55	d	2154.5	B	3336.6	b	1764	d	1206.3	f	2102.5	B
With	3592	a	2427	b	1293.3cd		2311.85	A	3706.6	a	2284	c	1294.6	e	2421.7	A
Mean	3485.1	A	2109.5	B	1104.9	C			3521.6	A	2024.3	B	1240.5	C		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Duncan's test.

Table 4: Mineral Fertilizer Rates and Azolla Impact on Nutrient Content of Zucchini Plants in Both Seasons

Azolla treatment	2022 season								2023 season							
	Fertilizer rate															
	100%		75%		50%		Mean		100%		75%		50%		Mean	
	N (%)															
Without	4.30	ab	3.92	c	2.32	e	3.51	B	4.35	b	3.45	c	2.52	e	3.44	B
With	4.45	a	4.26	b	2.65	d	3.79	A	4.44	a	4.36	b	2.63	d	3.81	A
Mean	4.37	A	4.09	B	2.48	C			4.39	A	3.91	B	2.57	C		
	P (%)															
Without	0.446	c	0.278	e	0.239	f	0.321	B	0.478	c	0.291	e	0.237	f	0.335	B
With	0.500	a	0.476	b	0.403	d	0.459	A	0.525	a	0.498	b	0.445	d	0.486	A
Mean	0.473	A	0.377	B	0.321	C			0.502	A	0.390	B	0.341	C		
	K (%)															
Without	3.956	c	2.778	e	2.401	f	3.046	B	3.994	c	3.734	d	2.357	f	3.362	B
With	4.336	a	3.981	b	3.684	d	4.000	A	4.381	a	4.084	b	2.878	e	3.781	A
Mean	4.146	A	3.379	B	3.043	C			4.188	A	3.909	B	2.617	C		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Duncan's test.

The interaction between mineral fertilizer rates and Azolla addition treatments displayed significant variance of N, P and K content in zucchini plants. The highest N, P and K content in plants performed by the recommended dose of mineral fertilizer with existing Azolla in soil treatment. The treatment of adding Azolla with 75% mineral fertilizer occupied the second highest N, P and K share in plants, followed by the recommended dose of mineral fertilizer with non-Azolla treatment. The lowest values of N, P and K content in plants exhibited by using 50% mineral fertilizer of the recommened dose with non-Azolla treatment.

3.3 Yield of Zucchini Fruits

Table 5 illustrated the yield of zucchini plant (yield/plot, yield/m^2 and fruit number/plant) under the different applied treatments at both studied seasons. The highest yield and fruit number of zucchini were produced as well with treatment of 100% mineral fertilizer, followed by the treatment of 75% mineral fertilizer. Finally, the lowest yield and fruits number/plant were found by the lowest mineral fertilizer rate (50%). As mentioned before at Table 4 and 5 that providing the plant with the adequate amount of the nutritional requirements that will promote the vegetative growth and N, p and K content of the plant. The enhanced vegetative growth of plants will activate photosynthesis, which reflected on increasing the yield (Habibi et al., 2011; Sarhan et al., 2011; Glala et al., 2012; Jahan et al., 2012; Abou-El-Hassan et al., 2014).

As expected the treatment of Azolla addition showed higher yield and fruit number of zucchini compared to non-Azolla treatment. The higher yield and fruit number with adding Azolla could be refered to the favorable impact of Azolla on immobile plant nutrient uptake (Mansour, 2007). Therefore, providing nutrients to be available for assimilation and good plant growth, would reflect as well with increasing the yield (El-Hifny et al., 2008; Shehata et al., 2012).

Regarding the interaction between mineral fertilizer rates and Azolla addition, significant impact was displayed on yield and fruit number of zucchini. The application of the recommended dose of mineratl fertilizer plus the addition of Azolla to the soil revealed the highest yield and number of fruits, followed by the recommended dose of mineratl fertilizer with non-Azolla treatment. The application of the 75% mineral fertilizer with Azolla addition to the soil treatment showed lower yield and number of fruits than the 100% mineral fertilizer with and without Azolla addition. The lowest yield and numer of fruits appeared by the lowest amount of mineral fertilizer with non-Azolla treatment, where applying insufficient nutritional requirements to the plants would drove to low growth of plants and that will affect as well to the yield (Feleafel et al., 2014; Naik et al., 2019).

3.4 Fruit Quality

The fruit quality of zucchini plants affected by all the applied treatments for oth studied seasons are discussed in Table 6. The fruit quality of zucchini plants is expressed as physical properties: fruit weight, fruit length, fruit diameter and fruit firmness, and chemical properties: TSS% and ascorbic acid content. The data in Table 7 showed a significant increament in fruit quality of zucchini plants that are treated with Azolla compared to non-treated ones.

Table 5: Effect Mineral Fertilizer Rates and Azolla on Yield And Fruit Number of Zucchini in Both Seasons

Azolla treatment	2022 season								2023 season							
	Fertilizer rate															
	100%		75%		50%		Mean		100%		75%		50%		Mean	
	Yield/plot (kg/4.5 m^2)															
Without	18.96	b	11.75	e	9.58	f	13.41	B	18.7	b	11.8	e	9.06	f	7.72	B
With	20.88	a	15.98	c	13.86	d	16.91	A	20.8	a	15.9	c	13.76	d	8.21	A
Mean	19.89	A	13.86	B	11.42	C			9.43	A	8.15	B	6.3	C		
	Yield (kg/m^2)															
Without	4.5	a	2.76	c	2.33	c	3.19	B	4.83	a	2.83	c	2.16	c	2.11	B
With	5	a	3.66	b	2.83	c	3.83	A	4.83	a	3.66	b	2.83	c	3.88	A
Mean	4.75	A	3.21	B	2.58	**B**			4.8	A	3.25	B	2.5	C		
	Fruit number /plant															
Without	14.3	b	11.33	c	9.66	d	11.77	B	15.33	a	11.66	c	9.33	d	13.88	B
With	16	a	13.33	b	11.33	c	13.55	A	16.33	a	13.66	b	11.66	c	12.11	A
Mean	15.16	A	12.33	B	10.5	C			15.83	A	12.66	B	10.5	C		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Duncan's test.

Table 6: Effect of Mineral Fertilizer Rates and Azolla on Physical And Chemical Properties of Zucchini Fruits In Both Seasons

Azolla treatment	2022 season								2023 season							
	Fertilizer rate															
	100%		75%		50%		Mean		100%		75%		50%		Mean	
	Fruit weight (g)															
Without	79.15	b	76.38	c	74.54	d	76.69	B	76.56	b	74.45	c	72.06	d	74.36	B
With	99.16	a	98.43	a	78.68	b	92.09	A	97.12	a	96.29	a	76.09	bc	89.83	A
Mean	89.16	A	87.43	B	79.63	C			86.86	A	85.36	A	74.06	B		
	Fruit length (cm)															
Without	12.83	b	12.36	cd	12.03	d	12.41	B	11.70	b	11.33	c	11.03	d	11.35	B
With	14.76	a	14.73	a	12.63	bc	14.04	A	14.20	a	14.13	a	11.53	bc	13.28	A
Mean	13.83	A	13.56	B	12.33	C			12.96	A	12.73	A	11.30	B		
	Fruit diameter (cm)															
Without	2.80	a	2.36	b	2.16	b	2.44	B	2.63	a	2.16	bc	1.93	c	2.24	B
With	2.96	a	2.93	a	2.66	a	2.85	A	2.80	a	2.73	a	2.43	ab	2.65	A
Mean	2.88	A	2.65	B	2.41	C			2.71	A	2.45	B	2.18	C		
	Firmness (kg/cm^2)															
Without	4.03	b	3.83	b	3.73	b	3.86	B	3.83	b	3.70	b	3.56	b	3.70	B
With	5.43	a	5.43	a	3.90	b	4.98	A	5.43	a	5.26	a	3.73	b	4.81	A
Mean	4.83	A	4.63	A	3.81	B			4.63	A	4.48	A	3.65	B		
	T.S.S (%)															
Without	4.093	c	3.743	d	3.009	f	3.615	B	4.115	c	3.853	d	3.076	f	3.681	B
With	4.786	a	4.322	b	3.375	e	4.161	A	4.795	a	4.462	b	3.342	e	4.199	A
Mean	4.44	A	4.03	B	3.19	C			4.455	A	4.157	B	3.209	C		
	Ascorbic acid (mg/100 g FW)															
Without	2.90	b	2.87	c	2.85	d	2.88	B	2.83	c	2.81	c	2.79	d	2.81	B
With	2.99	a	2.98	a	2.88	bc	2.95	A	2.96	a	2.94	b	2.83	c	2.91	A
Mean	2.95	A	2.93	B	2.86	C			2.90	A	2.88	B	2.81	C		

Means followed in same column by similar letters are not statistically different at 0.05 level according to Duncan's test.

In this regard, the recommened dose of mineral fertilizer treatment with Azolla addition had the highest improved fruit quality, followed by 75% of mineral fertilizer with adding Azolla with insignificant differences between them for the measured properties except for TSS% and ascorbic acid content at the second season. On the other hand, the lowest values of the measured properties demonestrated by 50% of mineral fertilizer with non-Azolla. Azolla treatments could promote the fruit quality as a result of vegetative growth enhancement. Therefore, application of Azolla could promote quality fruit such as fruit length, diameter, total soluble solids content and firmness compared to non-treated plants which showed the lowest values (Abou-El-Hassan et al., 2014). Furthermore, the soil Azolla injection before planting would afford high fruit peel quality, which is essential characteristics especially for fruits export.

3.5 Evaluation of Nutrient Use Efficiency

The NUE is the relation between the amont of the utilized mineral fertilizers and the obtained yield and how to get the highest yield with the less amount of mineral fertilizers. All the Azolla addition treatments showed higher NUE than the non-Azolla addition treatments for the same applied mineral fertilizer amount (Figure 1). The attitude of Azolla for increasing the NUE might be due to its role for helping to moderate the soil temperature, improve water hold capacity and crop nutrition (Ismail et al., 2010). The highest NUE by Azolla addition treatments was achieved by the lowest mineral fertilizer treatment and that is compatible with who stated that the lowest level of fertilization led to the highest (Qu et al., 2019; Singh et al., 2019). Lower NUE was reavealed by the 75% and 100% mineral fertilizer treatments with insignificant difference. However, the highest NUE value with non-Azolla treatments was recorded by the mean values for the highest and the lowest mineral fertilizer treatments, with insignificant differences between the first and second seasons and is related to the significant differences of yield and applied mineral fertilizers between them. Nevertheless, 75% mineral fertilizer treatment showed the lowest value among the non-Azolla addition treatments.

The highest NUE among the interaction between mineral fertilizer rates and Azolla addition treatments explained by the 50% mineral fertilizer, followed by 75% and 100% mineral fertilizer all with Azolla addition, while the lowest NUE was obtained by 75% mineral fertilizer with non-Azolla addition, which showed low yield close to 50% mineral fertilizer with non-Azolla addition, but with higher applied mineral fertilizer. The different attitude of 75% and 100% mineral fertilizer between Azolla and non-Azolla treatments is regarding to the higher gap of yield between 75% and 100% mineral fertilizer by non-Azolla treatments, where it was 2.2 and 2.5 kg/m^2 for seasons 2022 and 2023, respectively. Nevertheless, this gap was lower by the Azolla treatments, it was 1.5 kg/m^2 for both seasons.

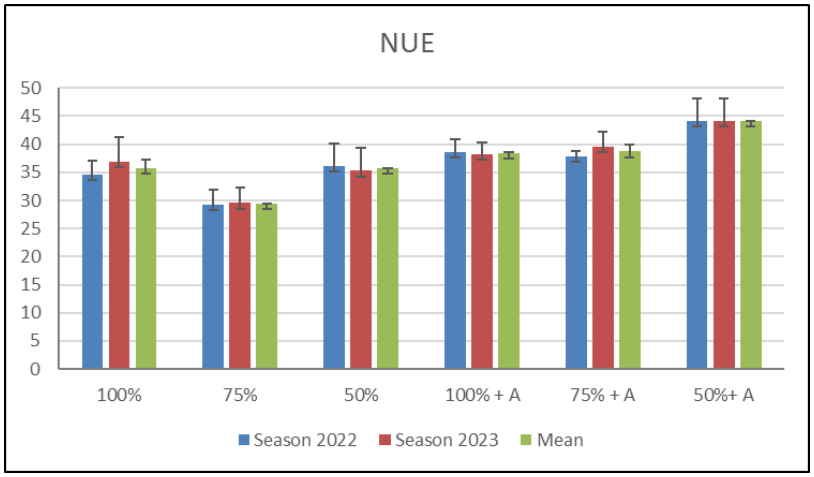

Figure 1: Nutrient Use Efficiency (NUE) of different treatments with g/m^2 of zucchini in both seasons (2022 and 2023). Percentage represented the mineral fertilizer treatment, and "A" represented the Azolla addition treatment.

Table 7: Economic Evaluation Indicators for Zucchini Production for the Agricultural Season 2022 and 2023 for The Whole Greenhouse.

Treatment	**100% F**		**75% F**		**50% F**		**100% F + A**		**75% F + A**		**50% F + A**	
Season	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Yield (kg)	1350	1449	828	849	699	648	1500	1449	1098	1098	849	849
Total variable costs	4705		4660		4616		4855		4810		4766	
Total fixed costs	Rental value of the greenhouse (540 m^2) = 2000 pounds											
Total costs	6705		6660		6616		6855		6810		6766	
Price per kg	The price per kilogram is 8.5 pounds for the first season, 10 for the second season*											
Total revenue	11475	14490	7038	8490	5941.5	6480	12750	14490	9333	10890	7216.5	8490
Revenue difference							1275	0	2295	2400	1275	2010
Net profit	4770	7785	378	1830	-674.5	-136	5895	7635	2523	4080	450.5	1724
Net profit difference							1125	-150	2145	2250	1125	1860
Gross margin	6770	9785	2378	3830	1325.5	1864	7895	9635	4523	6080	2450.5	3724
Relative profitability	0.70	0.80	0.16	0.48	-0.51	-0.07	0.75	0.79	0.56	0.67	0.18	0.46
Relative profitability difference							0.04	-0.003	0.40	0.19	0.69	0.54
Profitability of Invested Pound	0.71	1.16	0.06	0.27	-0.10	-0.02	0.86	1.11	0.37	0.60	0.07	0.25
Profitability of Invested Pound difference							0.15	-0.05	0.31	0.32	0.17	0.28

** Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, Cost and Net Return Bulletin.*
Source: Sample data for the agricultural seasons 2022 and 2023.
F: fertilization, A: Azolla.

3.6 Economic Evaluation

The displayed yield in Table (7) was calculated from Table (5) to represent the yield per greenhouse for the economic evaluation. The total costs in table 7 revealed the lowest value with the 50% fertilization with non-azolla treatment by 4,616 pounds, where it utilized the smallest amount of fertilization, while the highest total costs presented by the highest amount of fertilization (100%) in addition to the Azolla treatment with 4,855 pounds. The difference of total costs between the 100% of fertilization with and without Azolla addition is insignificant, where Azolla costs 150 pounds per greenhouse.

The highest total revenue was obtained by the recommended fertilization dose with Azolla addition, amounting 12,750 pounds. In the second

season, the total revenue of the recommended fertilization dose with and without Azolla were equal, regarding to the same production. The highest revenue difference between the same fertilization treatments with and without Azolla was achieved by 75% fertilization with Azolla addition, which exceeded the same treatment with non-Azolla addition by 2,295 and 2,400 pounds per greenhouse in the first and second season, respectively. Therefore, 75% fertilization with Azolla addition is better for sustaining revenue for the productive seasons

The net profit showed its highest value with the 100% fertilization + Azolla at about 5,895, 7,635 pounds, but the difference between fertilizing with Azolla and non-Azolla addition presented insignificant difference at the second season. As for 50% fertilization without Azolla addition, it achieved a loss over the two seasons amounting to about 675 and 136 pounds, respectively. The significant net profit difference represented by 75% fertilization with 2,145 and 2,250 pounds/greenhouse at the first and second seasons, respectively, where the 75% fertilization with Azolla addition showed double to 6.6 times higher values, with 2,523 and 4,080 pounds/greenhouse at the first and second seasons respectively, than the non-Azolla treatment pounds. The gross margin of 75% fertilization with Azolla addition exceeded its counterpart 75% fertilization with non-Azolla addition as well with almost the double.

The relative profitability revealed its highest value by the recommended dose fertilization + Azolla addition treatment, while almost zero difference between fertilizing with and without. On the contrary, the highest difference in profitability was presented by 50% fertilization, since the relative profitability of 50% fertilization without Azolla has a negative sign. The highest profitability of the invested pound was achieved by 100% fertilization + Azolla at the first season with 0.86 and by 100% fertilization without Azolla at the second season with 1.16. While, the highest difference in profitability of the invested pound for the three fertilization systems with Azolla compared to without was at 75% fertilization with Azolla addition, which was estimated at about 0.31 and 0.32 for the first and second seasons, respectively.

From the above, the recommended dose of fertilization with Azolla addition should the highest revenue and net profit with low to insignificant difference between the same fertilization dose with non-Azolla addition. While 75% fertilization with Azolla addition showed a high revenue and net profit with a significant difference (close to double) between the same fertilization dose with non-Azolla addition.

4. Conclusion

All vegetative growth properties, nutritional status of plants, yield and properties of zucchini fruits recorded the highest values with the highest applied rate of mineral fertilizer (recommended dose: 100%). The treated soil with Azolla improved the growth, NPK content of plants, yield and properties of zucchini fruits compared to untreated soil. The highest yield was produced by using 100% mineral fertilizer with adding Azolla. Noteworthy, application of 75% mineral fertilizers with adding Azolla had achieved higher nutrient content, physical and chemical properties than using 100% mineral fertilizer without Azolla, while application of 100% mineral fertilizer without Azolla had yield and fruit quality higher than using 75% mineral fertilizers with adding Azolla. Adding Azolla with different mineral fertilizer rates achieved superiority in nutrient use efficiency compared to non-adding Azolla. The highest nutrient use efficiency was achieved by using Azolla with 50% mineral fertilizer, which contributes to reducing environmental pollution and greenhouse gas emissions. The highest revenue and net profit appeared by 100% mineral fertilizers with adding Azolla, but with low to insignificant difference between the same fertilization dose with non-Azolla addition. While 75% mineral fertilizers with adding Azolla showed a high revenue and net profit with a significant difference (close to double) between the same fertilization dose with non-Azolla addition. Therefore, the Azolla addition had positive impact to zucchini, but with less fertilization its Azolla impact was more significant.

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