CROPPING SYSTEM AND FERTILIZER TYPE ON GROWTH AND YIELD OF CABBAGE

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ABSTRACT--*Less synthetic fertilizer is being used to grow cabbage (Brassica oleracea var. capitata L.) in a more sustainable manner. Increasing food production can no longer depend only on increased yield. Monocropping may not be the most efficient way to produce cabbage; intercropping may be a better way of managing available land. The study was carried out Babylon, Iraq, to evaluate performance of cropping systems, and fertilizer type, on growth of monocropped cabbage compared to intercropping cabbage with broad bean (Vicia faba L.). Fertilizer treatments were organic palm or rice residuals (each 20 $Mt{\cdot}ha^{-1}$) or synthetic fertilizer (300 $kg{\cdot}ha^{-1}$ 18N:18P:18K) control. Monocropped cabbage with the control fertilizer treatment produced the longest leaves, and the heaviest heads. Intercropping cabbage with palm residual produced the most wrapper leaves, greatest leaf area and the highest Vitamin C content. Intercropping cabbage and the control fertilizer produced the highest percent of chlorophyll and carotenoids. Intercropping cabbage with rice residual produced the heaviest heads, most marketable yield and highest percent of nitrogen and protein. Depending on production goals intercropping cabbage with beans and synthetic or organic fertilizer can be used to improve cabbage yield.*

Keywords--*Brassica oleracea var. captitata, intensive agriculture, vegetable production*

I. INTRODUCTION

Agriculture must provide food to a growing population and this will likely require a change in the way vegetable production is practiced (Boserup, 1981). One method of change is intercropping; growing at least 2 different crops at the same time and place (Sullivan, 2003). Socio-economic benefits for intercropping are decreases in pests, diseases, and weeds; improved water availability due to higher soil coverage; better access to nutrients, and improved production stability (Midmore, 1993).

Cabbage (*Brassica oleracea* L. var. *capitata*) contains glucosinolates and glutathione; is a rich source of vitamin C, has high fiber content and other nutrients beneficial to humans (Tatalay and Fahey, 2011; Yuras et al., 2011). Despite yield per unit area, return on investment at harvest is lower for cabbage compared to other vegetables. Broad bean (*Vicia faba* L.) is an important food legume consumed dry or fresh. Beans do not require large amounts of fertilizer because they stabilize atmospheric nitrogen through root nodules initiated by a bacterium. Intercropping cabbage with snap bean (*Phaseolus vulgaris* L.) did not affect yield of cabbage compared with monocropped cabbage (Guvenc and Yildirim, 2008). Intercropping cabbage with pea (*Pisum sativum* L.),

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produced decreased: numbers of leaves, total head weight, head yield, stem length and stem weight compared with monocropped cabbage (Masoud, 2013) and other crops (Choudhuri and Jana, 2012). Intercropping could be the most stable strategy to maintain sustainability of vegetable production.

For best plant growth, nutrients must be available in sufficient, balanced, quantities. Soil nutrients are largely unavailable to plants and only a small portion is released through biological activity and chemical processes (Barker and Pilbeam, 2015). Fertilizers are applied to increase nutrients in soil, but excess application of synthetic fertilizer can cause environmental degradation (Tisdale et al., 1997). Application of organic fertilizer may improve yield quality, and quantity, with fewer environmental concerns (Barker and Pilbeam, 2007). Organic fertilizers contain sugars, proteins, amino acids, and organic humic and non-humic acids, which contribute directly, or indirectly, to plant growth and development (Havlin, 2005). Application of organic fertilizers improves cabbage plant height, head diameter, dry matter, total yield, and percent nitrogen and potassium contents (Manea, 2017). The study was undertaken to determine effects of mono-cropping of cabbage or intercropping with broad bean, and fertilization with organic or synthetic fertilizer, on growth and yield of cabbage.

II. MATERIALS AND METHODS

The experiment was carried out at the Faculty of Agriculture, AL-Qasim Green University, Babylon, Iraq. Prior to the start of the experiment, random soil samples were obtained from 0-30 cm soil depth and analyzed at the Department of Horticulture, Faculty of Agriculture, to determine soil physical and chemical properties (Table 1). Cabbage, cv. Green Globe (Asia seed, Seoul, Korea), which matures in about 80 days, with an average head weight 1.8-2.3 kg growing under cold climate), and broad bean, cv. Luz de Otono (Semillas fito, Selva de Mar, Spain) were used. Treatments consisted of monocropped cabbage or a cabbage:broad bean intercrop and fertilizer provided as palm or rice residuals (each 20 $Mt{\cdot}ha^{-1}$ palm residuals which had been shredded and decomposed for 180 days, rice straw which had been chopped decomposed for 180 days). Large amounts were used because organic materials volatilize quickly under local conditions (Zaidi and Al Obeidi, 2017) or a synthetic fertilizer control (18N:18P:18K at 300 $kg{\cdot}ha^{-1}$). The experiment was arranged in a split-plot, within a randomized complete block design, with cropping as the main plot and fertilizer treatment as the subplot with 3 replications. The sandy loam soil was prepared by disking once. Plots were 3 m long and 0.75 m wide, with 2 furrow beds per plot (4 cabbage row in monocrop), and arranged with 1 m between treatments. Cabbage was spaced 50 cm between lines and 40 cm between plants in mono- and intercrop with 28 plants in treatments. In intercrops 2 rows of broad beans, 50 cm between rows, 20 cm between plants with 20 plants per row, were sown between 4 cabbage rows.

Table 1: Chemical and physical properties, and textural class of soil of the experimental site.

Parameter	Unit	Value
pH	- [a]	7.2
Electrical conductivity	$ds{\cdot}m^{-1}$	3.90
Organic matte	%	1.1
Total N	$mg{\cdot}kg^{-1}$	43

Available P	$mg\cdot kg^{-1}$	5.8
Exchangeable K	$mg\cdot kg^{-1}$	2.7
clay	%	19
sand	%	64
silt	%	17
Textural class	-	Sandy loam

[a] - = unitless.

Table 2: Characteristics of plant residuals obtained locally.

Parameter	Date palm residual	Rice residual
pH	7.03	6.50
Ec $dS\cdot m^{-1}$	2.63	0.93
C %	42.9	44.6
N %	2.60	2.48
C/N %	19.0	18.0
P %	0.61	0.54
K %	2.76	0.26
Ca %	2.83	1.30
Mg %	0.85	0.38
Na %	0.62	0.43
Fe %	0.42	0.25
Zn %	0.05	0.03
Mn %	0.01	0.01
Cu %	0.005	0.003
Source	Date palm	Rice
Water content %	30.0	6.50

To produce cabbage seedlings seed were sown in 68 × 40 cm Styrofoam trays containing 209 cells containing peat moss on 25 August 2018. Developing seedlings were fertilized with 1 $g\cdot L^{-1}$ of liquid poultry litter extract (4N-1P-5K) 3 times spaced 10 days apart. Trays were placed in a greenhouse (27°C and 70% humidity) and each tray supplied with 3 L of water per day with a watering can. Additional irrigation occurred weekly with 1 L of water per seedling tray. Prior to planting irrigation drip tape, 20 cm between emitters, spaced 40 cm between irrigation lines, was laid down and beds covered with black polyethylene (150 µm thick) plastic. Cabbage seedlings were hand transplanted on 5 October 2018 and seed of broad bean sown after holes were cut in the plastic on 12 October 2018. Control of leaf caterpillars was with cybermethrin (Syngenta, Basel, Switzerland) at 1.5 $mL\cdot L^{-1}$.

When heads reached marketable size and quality, 10 plants, chosen at random, were assessed for leaf length, number of wrapper leaves, total leaf area was determined following Watson and Watson (1953), chlorophyll determined following Godwin (1976), head diameter, total head weight, marketable head weight, marketable yield, percent nitrogen and protein and contents of carotenoids and Vitamin C in fresh leaves. All observations were made on plants from center rows to avoid edge effects. Numbers of wrapper leaves were determined by counting each green leaf on the cabbage head. Samples were collected from leaves for 5 cabbage plants from the center of each plot after harvest for chemical analyses. Samples were dried in a ventilated oven at 69±1°C and wet-digestion was with sulfuric-perchloric acid and total nitrogen determined using the micro-Kjeldahl method (Al-Sahaf, 1989). Carotenoids and Vitamin C were determined spectrophotometrically (Frank, 1975; Abbas and Abbas, 1992).

Data were subjected to analysis of variance using Genstat 2012 (Release 4.23DE, Lawes Agricultural Trust, Rothamsted Experiment Station, Hertfordshire, U.K.). If the interaction was significant it was used to explain results. If the interaction was not significant, means were separated using the least significance difference (Al-Rawi and Khalaf Allah, 2000).

III. RESULTS AND DISCUSSION

Fertilizer type affected numbers of wrapper leaves, the interaction affected all measured variables (Table 3). The interaction of monocropped cabbage treated with synthetic fertilizer produced leaves of similar length to all treatments except monocropped cabbage receiving palm residual which had the smallest leaves (Table 4). The fewest wrapper leaves were on plants in the intercrop receiving rice residual. The generally greater leaf area was in the intercrop receiving the synthetic control. The lowest leaf area was for monocropped cabbage receiving palm residual (Table 4). The exception was for plants in the intercrop receiving palm residuals which had a higher leaf area. Chlorophyll contents in the monocrop were similar except for plants receiving palm and rice residuals, which were lower (Table 4). In the intercrop chlorophyll was highest in plants receiving synthetic fertilizer.

Table 3: ANOVA responses due to fertilizer, cropping and their interaction on leaf length, number of wrapper leaves, leaf area and chlorophyll.

Source	Leaf length	Number of wrapper leaves	Leaf area	Chlorophyll
Fertilizer type (F)	ns	**	ns	ns
Cropping system (S)	ns	ns	ns	ns
Interaction				
F × S	*	**	*	*

ns, *, ** not significant or significant at P<0.05 of P<0.01, ANOVA.

Table 4: Interaction effect due to cropping[a] and fertilizer on leaf length, number of wrapper leaves, leaf area, and chlorophyll.

		Leaf area	

Cropping system ×	Fertilizer type	Leaf length (cm)	Number wrapper leaves	(cm^2)	Chlorophyll (Spad)
Monocrop cabbage	Palm residual	19.20	40.50	15412	3.02
	Rice residual	23.41	40.33	18327	2.83
	Control[b]	24.11	41.50	20944	3.48
Intercropped cabbage:bean	Palm residual	23.75	43.17	27614	3.33
	Rice residual	22.42	37.50	18257	3.47
	Control[b]	24.03	38.67	20509	4.11
LSD 0.01		ns	4.71	ns	ns
LSD 0.05		4.12	3.30	8313	1.02

[a] The interaction analyzed with Least Squares Means at 5 and 1% levels, means separated with LSD.

[b] control: 300 kg·ha^{-1} NPK (18:18:18); Palm residuals and Rice residuals: 20 Mt·ha^{-1}.

Fertilizer affected head diameter, marketable head weight and marketable yield but not total head weight; cropping did not affect responses, but the interaction affected all measured variables (Table 5). Head diameter, head weight, marketable head yield and marketable yield were generally similar regardless of fertilizer type. The exception was for plants in the monocrop receiving palm residual which had lower values (Table 6).

Table 5: ANOVA responses due to fertilizer, cropping and their interaction on head diameter, marketable head weight and marketable yield.

Source	Head diameter	Total head weight	Marketable head weight	Marketable yield
Fertilizer type (F)	*	ns	*	*
Cropping system (S)	ns	ns	ns	ns
Interaction				
F × S	**	**	**	**

ns, *, ** not significant or significant at P<0.05 of P<0.01, ANOVA.

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Table 6: Interaction effect due to cropping and fertilizer on head diameter, total head weight, marketable head weight, and marketable yield.

Cropping system	×	Fertilizer type	Head diameter (cm)	Total Head Weight (kg)	Marketable head weight (kg)	Marketable Yield ($Mt\cdot ha^{-1}$)
Monocrop cabbage		Palm residual	15.34	1.71	1.37	73.2
		Rice residual	18.05	2.38	1.71	91.1
		Control[b]	19.63	2.90	2.12	113.0
Intercropped cabbage:bean		Palm residual	18.98	2.67	1.96	104.3
		Rice residual	17.87	2.46	1.80	96.0
		Control[b]	19.00	2.78	2.48	121.1
	LSD 0.01		3.93	1.17	0.986	42.5
	LSD 0.05		2.75	0.819	0.692	31.9

[a] The interaction analyzed with Least Squares Means at 5 and 1% levels; means separated with LSD.

[b] control: 300 $kg\cdot ha^{-1}$ NPK (18:18:18); Palm residuals and Rice residuals: 20 $Mt\cdot ha^{-1}$.

Fertilizer type affected percent nitrogen and protein; intercropping affected carotenoids and Vitamin C contents, and the interaction affected all measured variables (Table 7). The interaction of fertilizer and intercropping affected all quality parameters (Table 8). Percent nitrogen in monocropped plants receiving rice residuals was highest compared to intercropped plants receiving rice residuals. In the intercrop the percent nitrogen was lowest for plants receiving palm residual. Monocropped plants receiving rice residual and synthetic fertilizer were similar. Percent protein in monocropped plants was highest for those receiving rice residuals. In the intercrop there was no difference in percent protein due to treatment.

Table 7: ANOVA responses due to fertilizer, cropping and their interaction on percent of nitrogen and protein, and carotenoid and Vitamin C contents.

Source	% N	% protein	Carotenoids	Vitamin C
Fertilizer type (F)	**	**	ns	ns
Cropping system (S)	ns	ns	*	*
Interaction				

ns, *, ** not significant or significant at P<0.05 of P<0.01, ANOVA.

F × S	*	*	**	*

Table 8: Interaction effect due to cropping and fertilizer on percent of nitrogen and percent protein and carotenoid and Vitamin C contents.

[a] the

Cropping system ×	Fertilizer type	% N	% Protein	Carotenoids (mg/100 g fresh weight)	Vitamin C (mg/100 g fresh weight)
Monocrop cabbage	Palm residual	1.23	7.73	0.109	91.2
	Rice residual	1.29	8.08	0.115	86.6
	Control[b]	1.20	7.55	0.135	82.1
Intercropped cabbage:bean	Palm residual	1.10	6.88	0.133	144.9
	Rice residual	1.49	9.31	0.141	135.9
	Control[b]	1.30	8.17	0.163	74.7
LSD 0.01		ns	ns	0.051	ns
LSD 0.05		0.233	1.45	0.036	57.7

interaction analyzed with Least Squares Means at 5 and 1% levels; means separated with LSD.

[b] control: 300 kg·ha^{-1} NPK (18:18:18); Palm residuals and Rice residuals: 20 Mt·ha^{-1}.

Carotenoid levels were generally not affected by treatment. The exception was for monocropped plants receiving palm residuals which had the least carotenoids. Levels of Vitamin C for monocropped plants were highest when they received rice residuals. In the intercrop Vitamin C levels were highest for plants receiving residuals of both plants. Manure releases nutrients for plant use over time and improves soil structure, retains nutrient and water, improves aeration, and aids in better response of crops to fertilizer (Vimala et al, 2006).

There was a total of 72 measurements in the interaction, 6 categories and 12 measured variables. Overall synthetic fertilizer was better than 1 organic treatment 22% of the time; palm residual was better than synthetic fertilizer 4% of the time, and rice residual was better than synthetic fertilizer 5% of the time. Of the remaining 68% of the time there were no differences. The best yield quantity obtained from synthetic fertilizers is attributed to rapid mineralization of N, P, K. For better than 2/3 of treatments there was no difference between synthetic or organic fertilizers; when there was a difference, based on a category of fertilizer, the synthetic fertilizer and the 2 organic fertilizers taken together were essentially equal. Better yield for cabbage can be achieved provided that synthetic fertilizer and intercrop.

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