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EFFECTS OF NITROGEN, ORGANIC MANURE AND BIOFERTILIZER APPLICATIONS ON STRAWBERRY PLANTS

II. YIELD AND FRUIT QUALITY

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ABSTRACT

Field investigations were conducted during the summer seasons of 1999/2000 and 2000/2001 to study the responses of strawberry plants cv. "Camarosa" to different levels of nitrogen (0, 200,300 and 400kg N fed.$^{-1}$), organic manure (0, 15, 20 and 25 m^3 fed. $^{-1}$) and biofertilizer treatments (inoculation with or without "Halex-2") as well as their interactions on yield potentials and fruit quality of strawberry. The two experiments were carried out on sandy soils under a drip irrigation system, at the Experimental Station Farm, South Tahrir, Hoticultural Research Station, situated at Behiera Governorate. The obtained results, generally, indicated that increasing of nitrogen or chicken manure applied rates was accompanied with significant increases for yield potentials; i.e, yield plant^{-1}, early yield and total yield fed. $^{-1}$,and marketable yield fed.$^{-1}$ as well as average fruit weight. On the contrary, the incremental additions of either nitrogen or organic manure tended to decrease total soluble solids, total titratable acidity and Vitamin C contents of strawberry fruits. Total sugars responded significantly and negatively to mineral nitrogen applications but it responded positively with increasing the chicken manure rates.

The inoculation of strawberry transplants with "Halex-2" biofertilizer improved strawberry fruit yield and its components, as well as, enhanced average fruit weight and total

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sugars. Reverse results were obtained for T.S.S., T.T.A. and V.C contents. Application of 300 kg N fed.$^{-1}$ or 25 m^{3} chicken manure fed.$^{-1}$ combined with "Halex-2" biofertilizer appeared to be the most efficient treatment combination for a higher yield potentials of strawberry, under the conditions of this investigation.

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch) is one of the most popular vegetable crops. In Egypt, it occupies an important position among the untraditional vegetable crops due to its multifarious use as local fresh consumption, food processing and exportation. The crop is commonly grown in sandy soils for getting early yields and good fruit quality. Sandy soils have their own problems as single grain structure, susceptibility to erosion, and low levels of nutrients and organic matter as well as microorganisms (Nour, 1999). Owing to their poverty in nutrients and organic matter, fertilizer requirements of strawberry plants grown in such soils, are quite high. The excessive use of inorganic fertilizers might cause ground water contamination and environmental hazards, in addition to their high costs (Lee, 1992). Thus substitution of inorganic fertilizers with organic sources is needed.

The value of organic fertilizers as a source of humus, macro- and micro-nutrients, as well as increase the activity of the useful microorganisms has been reviewed by El-Gizy (1994). The beneficial effects of organic manure on strawberry yield were early reported by Hitz (1951) and later by Mohamed and Gabr (2002). Strawberry yield was the highest with using chicken manure at 14 t/ha compared to the use of ammonium nitrate at the rate 150 kg N/ha. (Rubeiz *et al.,* 1998). Conflicting results were recorded by Nonnecke and Christian (1997), who stated positively decreasing in fruit yield and weight of strawberry due to the use of corn gluten as organic source. Considering the quality of strawberry treated with organic manure, results of Cayuela *et al*. (1997) showed that fruits had superior quality in terms of more intense color, higher sugar and dry matter content than fruits from traditional NPK

fertilization.

Biofertilization method plays an important role in the plant nutritional requirements. Whereas, biofertilizers enhance crop productivity through nitrogen fixation, phosphate solubilization, plant hormone production, ammonia excretion and controlling various plant diseases (Pathak *et al.*, 1997; Hedge *et al.*, 1999). Biofertilizers, also, are ecofriendly which at any rate cannot replace chemical fertilizers that are indispensable for getting maximum yield of crops (Hedge *et al.*, 1999). Significant effects of biofertilizers on yield and its components of some fruit vegetables have been reported by several investigators (Barakat and Gabr, 1998 on tomato; Shiboob, 2000 on common bean).

Therefore, the objective of this work was to evaluate the effects of inorganic nitrogen, organic manure and biofertilizer applications, and their combinations on yield potentials and fruit quality of strawberry.

MATERIALS AND METHODS

Two field experiments were conducted during the summer seasons of 1999/2000 and 2000/2001 at South Tahrir district, newly reclaimed sandy soils, in the Experimental Station Farm, Horticultural Research Station, situated at Behiera Governorate, under a drip irrigation system.

Prior to executing the experiments, the soil's physico-chemical properties of the two experimental sites, were determined according to the methods described by Black (1965). The results of these analyses are presented in Table 1.

Table 1. Physical and chemical analyses of the two experimental sites in 1999/ 2000 and 2000/ 2001seasons.

Seasons	Physcial properties				Chemical Properties								
	Sand %	Silt %	Clay %	Texture	EC (ds/ ms)	PH	Soluble cation (meq/I)			Soulble anion (meq/I)			Total N (%)
							Ca^{++}	Mg^{+}	K^{+}	HCO^{-}_{3}	Cl^{-}	SO_4	
1999/2000	94	4	2	sandy	0.16	8.70	0.74	0.54	0.22	0.57	0.40	0.59	0.007
2000/2001	94	5	1	Sandy	0.20	8.90	0.69	0.56	0.19	0.54	0.41	0.57	0.009

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Each experiment comprised 32 treatments representing all possible combinations of four N fertilizer levels (0, 200, 300 and 400 kg N fed.$^{-1}$), four organic manure rates (0, 15, 20 and 25 m^3 fed.$^{-1}$) and two biofertilizer treatments (uninoculated and inoculated with "Halex-2"). Ammonium sulphate (20.5%N) and chicken manure were the respective sources of the inorganic nitrogen and organic fertilizers, consecutively.

Inorganic nitrogen fertilizer was added through the drip irrigation system during the growing season; while, chicken manure was uniformly added during soil preparation. Table 2, illustrated the chemical analyses of the utilized organic manure in both seasons. However, "Halex-2" is a biofertilizer containing a mixture of non symbiotic N-fixing bacteria of the genera *Azospirillum, Azotobacter* and *klebsiella*, which was supplied by the Biofertilization Unit, Plant Pathology Department, Alex. Univ., and was used at the rate of 400 g fed.$^{-1}$.

Table 2. Chemical properties of the chicken manure during the two growing seasons of 1999/ 2000 and 2000/2001.

Properties / Seasons	N %	P %	K %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	Ec (ds/ms)	PH	O.M (%)
1999/2000	2.92	0.94	1.22	6394	364	115	54	11.7	7.18	40.6
2000/2001	3.13	0.63	1.29	4252	197	120.5	32	10.67	7.44	35.7

The experimental layout was split-split-plot system in a randomized complete blocks design with four replications. Nitrogen fertilizer levels were arranged as the main plots, chicken manure rates were considered as the sub-plots; while, the biofertilizer treatments were taken as sub-sub-plots. Each sub-sub-plot was 6.25 m long and 0.7 m width. Thus the area of the smallest experimental unit was 4.37 square meters.

Frigo transplants of Camarosa cultivar were obtained from local nurseries under the supervision of Strawberry Improvement Center of Ain Shams University. They were treated with fungicide (Topsin M-70 at the rate of 2 g liter-1) for 20 minutes, before the inoculation process which was carried out by immersing the roots of transplants in "Halex-2" cell

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suspension (4 x 10^7 cells ml^{-1}) for 15 minutes just before transplanting. Arabic gum solution (5%) was used as an adhesive agent. The transplants of the uninoculated control were dipped in distilled water . Then, the transplants took place on the two sides of the row on October 1, 1999 and September 25, 2000 with interrow spacing of 25 cm. After two weeks from transplanting, the inoculation process again repeated by sidedressing the inoculum suspension beside the plants.

All experimental plots received a basal soil dressing, during soil preparation, at the rates of 46.5 kg P_2O_5 and 72 kg K_2O as calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), orderly. While , during the entire growing season, the rest of phosphorus and potassium fertilizers were added through the drip irrigation system four times per week, at the rates of 80 kg P_2O_5 fed.$^{-1}$ in the form of phosphoric acid (80% P_2O_5) and 120 kg K_2O as potassium sulphate (48% K_2O).

A mixture of micro-elements including Fe, 3.88%; Mn, 1.73%; Cu, 1.6%; B, 0.8%; Mo, 0.033% and Zn 0.5% were foliar sprayed at four weeks intervals starting from one month after transplanting and was continued throughout the growing seasons. All of the horticultural procedures were applied as recommended for strawberry commercial production.

The developed flowers and runners were removed during the first month to enhance the vegetative growth before flowering stage. Fruits were harvested after 6 months from transplanting at the full ripe stage in the early morning. Picking started on March and extended to June, in the two summer seasons.

Data Recorded

a. **Early fruit yield (ton fed.$^{-1}$),** was calculated as the fresh weight of harvested fruits from the first four pickings.
b. **Total yield (ton fed.$^{-1}$),** was calculated as the fresh weight of all harvested fruits all over growing the season. It included marketable and non marketable fruit yield (culls yield).
c. **Marketable yield (ton fed. $^{-1}$)**
d. **Non marketable yield (ton fed.$^{-1}$),** included splitted, malformed, green shouldered, water damaged and rotted fruit.
e. **Fruit quality characteristics :** Random samples of ten fruits were

taken from each sub-sub plot, at the peak of harvesting period (the first week of April) to determine average fruit weight (g), total soluble soilds (T.S.S.%) using hand refractometer, total titratable acididy (TAA) as g of citric acid/ 100 g fruit juice according to A.O.A.C. (1990), total sugars (%) were determined in dry matter of a random fruit sample according to Nelson (1974).Vitamin C. content (V.C.) was determined as mg/ 100g fresh weight using 2.6 dichlorophenol indophenol as indicator for titration as outlined in A.O.A.C. (1990).

All obtained data were statistically analysed according to Costat Software (1985) and the Revised L.S.D. test was used to compare the differences among the treatments as outlined by Smith (1978).

RESULTS AND DISCUSSION

Fruit yield and its components

The results presented in Table 3, clearly, indicated that there were progressive and significant increases on all studied yield parameters, i.e.; early yield, total yield, marketable and culls yield fed.$^{-1}$ as well as yield plant^{-1} due to increasing the N applied rate up to 300 or 400 kg N fed.$^{-1}$, in both seasons. The increments in total fruit yield at 200, 300 and 400 kg N fed.$^{-1}$ over the control were 13.32, 19.29 and 21.91%, orderly, as average of the two seasons. Such responses of strawberry yield to N-fertilization appeared to be in general accordance with those reported by several investigators (Albregts and Howard, 1987; Moussa *et al.*, 1993; Neuweiler, 1997; Kreusel and Lenz, 1998).

Concerning the effects of organic manure rates on strawberry yield and its components, the results in Table 3 indicated that the

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application of 25 m^3 chicken manure fed.$^{-1}$, gave the highest significant early and total yield fed.$^{-1}$ as well as yield plant^{-1} relative to the other used rates, in both seasons. The total yield of strawberry, as an average of the two seasons, increased by 9.02, 16.83 and 19.47% over the control as a result of using 15, 20, 25 m^3 chicken manure fed.$^{-1}$, orderly Such a result can be explained on the basis that the sandy soils of the experimental sites have relatively low amounts of nutrients (Table 1), thus the application of chicken manure at the high rate of 25 m^3 fed.$^{-1}$ improved the physical , chemical and biological properties of the soil during the growing period which was reflected on strawberry fruit yield. El-Nagar (1996) reported that the incorporation of organic manures in sandy soils can increase nutrient availability, cation exchange capacity, organic matter content, and this, in turn, stimulates plant growth and productivity. Recent studies indicated that composted manure has the potential to foster the biological process in soil, help in the creation and preservation of soil fertility (Funt and Bierman, 2000; Meissner-Smejkal, 2000). Such effects might have contributed to the increased in strawberry yield as previously report by Albergts and Howard (1981), Rubeiz *et al.* (1998) and Mohamed and Gabr (2002).

Regarding the effects of the inoculation with the biofertilizer "Halex-2" on the yield potentials of strawberry, the results in Table 3 showed that the inoculation treatment caused significant increases on all studied yield parameters expressed as early yield, total yield fed.$^{-1}$ and marketable and culls yield fed.$^{-1}$, in addition to yield plant^{-1}, compared with those of the uninoculated control treatment, in both seasons. The increments in early and total yield fed.$^{-1}$, as average of the two seasons, were 18.03% and 9.52%, orderly. Recently, similar findings were, generally, obtained by Shiboob (2000) on common bean, and Gabr *et al.*, (2001), on pepper. The stimulatory effect of N_2-fixers on plant growth and productivity can be attributed not only to N_2-fixation activity, but also to the production of growth promoting substances (Jagnow *et al.*, 1991). Likewise, Hedge *et al.* (1999) concluded that the mechanisms by which the plants inoculated with azotobacters derive positive benefits in terms of increased yield, plant biomass and N-uptake, are attributed to biological

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N_2-fixation, development and branching of roots, production of plant growth hormones, enhancement of nutrient uptake, improved water status of plant, increased nitrate reductase activity and production of antibacterial compounds.

The results in Table 4 illustrated the interaction effects between the different rates of nitrogen fertilizer and organic manure on the yield and its parameters which were found significant, in both seasons. The treatment combinations of addition inorganic nitrogen fertilizer at the rate of 300 kg N fed.$^{-1}$ coupled with 25 m^3 chicken manure fed.$^{-1}$, generally, produced the highest significant mean value for strawberry yield and its components. It was, also, noticed that this treatment combination was not differ significantly compared with those of the application of 400 kg N fed.$^{-1}$ + 20 or 25 m^3 chicken manure fed.$^{-1}$ The previous result indicated that using chicken manure had a beneficial effect on reducing the amount of mineral nitrogen from 400 to 300 kg N fed.$^{-1}$. The obtained results are in general accordance with those reported by Kopanski and Kawecki (1994) who stated that the application of nitrogen fertilizer combined with organic manure (FYM) was more effective and increased strawberry yield.

The comparisons among the means of different combinations of nitrogen rates and biofertilizer treatments for the yield potentials of strawberry are shown in Table 5. All the studied yield parameters were found to be significantly affected by these interaction treatments, with only one exception for the early yield which did not reflect significant differences, in both seasons. The application of 300 kg N fed.$^{-1}$ coupled by biofertilizer inoculation with “Halex-2”, generally, produced the highest mean values for total yield, marketable and culls yield and yield plant^{-1}. It was also noticed that this treatment combination was not differ significantly compared to the treatment combination of 400 kg N fed.$^{-1}$ + biofertilizer inoculation. Similar results were also recorded by Dawa *et al.* (2000), who stated that using a mixture of mineral fertilizer and biofertilizer resulted in a positive reflection on tomato yield.

The results in Table 5, clearly, show some significant differences due to the interaction effects between different organic manure rates and

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biofertilizer treatments on the strawberry yield plant^{-1}, in both seasons. However, the results indicated also that the early and total yield as well as the marketable and culls yield were not significantly affected by this type of interaction. The comparisons among the means of the various combinations, clearly, indicated that the application of chicken manure either at the rate of 20 or 25 m^3 fed.$^{-1}$ coupled with inoculation by the biofertilizer "Halex-2" , gave the highest mean value of yield plant^{-1}.

The results presented in Tables 6 and 7 indicated the presence of the second order interactions among the used rates of mineral nitrogen, organic manure and biofertilizer treatments. The differences among the mean values of the various treatment combinations, for all the studied yield potentials, were found significant, in both seasons. The best treatment combination appeared to be that of using 300 kg N fed.$^{-1}$ + 25m^3 organic manure + "Halex-2" inoculation, which resulted in the highest mean values of strawberry yield and its components.

Fruit quality characteristics

The results in Table 8, generally, showed the presence of some significant differences on the quality of strawberry fruits, as a result of increasing N fertilizer applications, in both growing seasons. The fruits which produced from plants that fertilized with N at the rate of 400 kg fed.$^{-1}$ characterized by the lowest contents of total soluble solids, total titratable acidity, total sugars and Vitamin C. On the other hand, a reverse trend was noticed for average fruit weight, where the application of 400 kg N fed.$^{-1}$ was associated with significant increase in average fruit weight . The negative relationship between N-supplying and fruit sugar contents could be supported by the results obtained by El -Shal *et al.* (1993), who stated that the higher N application produced fruits with lower sugars content. The opposing effects of N on sugars content could be attributed to that, under high N conditions greater amounts of carbohydrates probably directed and utilized in maintaining vigorous vegetative growth and a little proportions may be left to supply the growing fruits with sufficient carbohydrates. The observed reduction in fruit total soluble solids might be due to the corresponding decrement in the sugars content which make up 70-80% of T.S.S. as stated by

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Culpepper *et al.* (1935). Similar results were, also, reported by Voth *et al.* (1967) and El-Gizy (1978).

Concerning the effects of organic manure rates, the results in Table 8 showed clearly that increasing the chicken manure rate from 0 to 25 m^3 fed. $^{-1}$ reflected significant and progressive increase on both average fruit weight and total sugars. On the other hand, the use of chicken manure resulted in some reductions on both T.S.S. (%), total titratable acidity and V.C. contents. However, in the case of T.S.S the three used additions of chicken manure did not show any significant differences; whereas, in the case of V.C. the highest rate of organic manure showed a significant reduction relative to the unmanured control treatment and the other two rates. The previous results, concerning average fruit weight and total sugars, are in general agreements with those reported by Cayuela *et al.* (1997) and Mohamed and Gabr (2002). Reversaly results regarding the other studied fruit quality were obtained by El-Sheikh and Salama (1997), Abd-Allah *et al.* (2001) on tomato , and Aly (2002) on cucumber, who reported that increasing organic fertilizer rates improved fruit TSS, vitamin C and total titratable acidity.

Inoculation strawberry transplants with the biofertilizer “Halex-2” was responsible for the significant increments for average fruit weight and total sugars compared to the uninoculated treatment, in both seasons. However, significant reductions in T.S.S, total titratable acidity and V.C. contents due to biofertilizer treatments were detected, in the two studied experiments. The obtained results, generally, compatible with those reported by Gabr *et al.* (2001) on sweet pepper regarding average fruit weight and total sugars.

The interaction effects among the used different inorganic nitrogen fertilizer and organic manure rates on the quality of strawberry fruits are shown in Table 9. The comparisons among the means of the various treatment combinations showed the presence of some significant interaction effects on fruit quality characteristics, in both seasons. The highest average fruit weight was obtained from the application of 400 kg N fed. $^{-1}$ combined with the use of 25 m^3 organic manure fed. $^{-1}$ On the other side, the plants which were fertilized with organic manure at the

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rate of 20 or 25 m^3 fed. $^{-1}$ without N fertilization produced fruits with the highest T.S.S and total sugar contents, in both seasons. On the other extreme, the highest V.C. content resulted from the unfertilized plants either by N or organic manure . However, titratable acidity did not reflect any significant differences due to the interaction effects between mineral N and organic manure rates.

The comparisons among the means of different combinations of nitrogen rates by biofertilizer treatments for the fruit quality of strawberry are illustrated in Table 10. Average fruit weight , total sugars and total titratable acidity were found to be significantly affected by such interactions . However, T.S.S and V.C contents were not affected. The combined treatment (400 kg N fed. $^{-1}$ plus biofertilizer inoculation with "Halex-2") produced the highest mean value for average fruit weight . The previous treatment combination, also, produced strawberry fruits with the lowest value of total titratable acidity. Meanwhile, the highest acidity content was recorded for the unfertilized control whether inoculated with "Halex-2" or not, in both seasons.

The interaction effects between organic manure application and "Halex-2" biofertilizer exhibited some significant differences for average fruit weight and total sugars content. Fruit T.S.S., total titratable acidity and V.C. contents did not reflect any significant differences , in both seasons (Table 10) . It was noticed that the highest mean values for average fruit weight and total sugar content were obtained from the application of chicken manure at the rate of 25 m^3 fed. $^{-1}$ with the presence of "Halex-2" biofertilizer, in both growing seasons.

Data presented in Table 11 indicated the presence of the second order interactions among nitrogen fertilizer, organic manure rates and bioferilizer treatments. The differences among the mean values of the treatment combinations for average fruit weight were found significant; while those of T.S.S., total titratable acidity, total sugar, V.C. content appeared insignificant. Therefore, Table 11 shows only the results of average fruit weight. The best treatment combination for average fruit weight appeared to be that of using 400 kg N fed. $^{-1}$ + 20 or 25 m^3 chicken manure fed. $^{-1}$ + "Halex-2" inoculation, in both seasons. In conclusion, the

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present study indicated that strawberry grown under the conditions of sandy soils produce high yield by using mineral nitrogen, chicken manure and inoculated with "Halex-2". The best treatment combination appared to be that of using 300 kg N fed.$^{-1}$ + 25 m^{3} organic manure + "Halex-2" inoculation.

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الملخص العربي

تأثير التسميد النتروجيني والعضوى والحيوى على نباتات الفراولة
2-المحصول وجودة الثمار

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أجريت دراسة حقلية خلال الموسم الصيفى لعامى 1999-2000 ، 2000-2001 بأرض رملية بمحطة التجارب الزراعية بجنوب التحرير ، التابعة لمعهد بحوث البساتين بمحافظة البحيرة ، بهدف دراسة استجابة نباتات الفراولة صنف (كماروزا) لأربعة مستويات مختلفة من التسميد النتروجيني (صفر , 200 ,300 ,400كجم ن/فدن) وأربعة معدلات من سماد زرق الدواجن (صفر، 15 ,20 ,25 م3/فدان) وكذلك لمعاملتى التسميد الحيوى (معامل وغير معامل بالهاليكس-2) ، بالإضافة إلى تأثير التداخل بينهم وذلك على القدرة المحصولية وجودة ثمار الفراولة .

أوضحت النتائج أن زيادة معدل كل من السماد النتروجيني والسماد العضوى (زرق الدواجن) قد أدت إلى زيادة القدرة المحصولية لنباتات الفراولة معبراً عنها بمتوسط محصول النبات ، والمحصول المبكر والكلى للفدان ، وكذلك كمية المحصول القابل للتسويق .كما أظهرت النتائج أن المعاملات السالفة الذكر أدت إلى زيادة متوسط وزن الثمرة .وعلى النقيض من ذلك فإن الإضافة المتزايدة من كل من النتروجين والسماد العضوى أدت إلى قلة النسبة المئوية للمواد الصلبة الذائبة والحموضة الكلية ومحتوى فيتامين ج فى الثمار .كما وأن كمية السكريات الكلية استجابت إيجابيا لزيادة معدل السماد العضوى وعلى العكس استجابت سلبيا لزيادة معدل النتروجين المضاف .أما بالنسبة لاستخدام التلقيح بالسماد الحيوى "هاليكس-2" أدى إلى تحسين كمية المحصول ومكوناته متحتوى الثمارمن السكريات الكلية .كما لوحظ أن استخدام السماد الحيوى السالف الذكر قد أدى إلى إنخفاض كل من المواد الصلبة الذائبة والحموضة الكلية وفيتامين ج في ثمار الفراولة.

وعموما فتحت ظروف هذه الدراسة، أدت إضافة 300كجم ن/فدان أو 25م3 زرق دواجن/فدان بالإضافة إلى التلقيح البكتيرى "بالهاليكس-2 " إلى الحصول على أعلى محصول من الفراولة .