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INTERACTION OF PLANT DENSITY AND PHOSPHORUS-POTASSIC FERTILIZATION ON TOMATO PRODUCTION AND FERTILIZERS USE EFFICIENCY

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ABSTRCT

Field investigation was conducted during the fall seasons of 2000 and 2001 to study effects of spacing and P-K fertilization on tomato (*Lycopersicon esculentun*, Mill.) production and quality, and fertilizers use efficiency, in a newly reclaimed calcareous soil. The obtained results indicated that planting tomato transplants at 20cm, significantly gave greater early and total yield than 40cm. However, a reverse trend was true for average fruit weight. Fertilizing tomato plants with 60 kg P_2O_5 + 72 kg K_2O fed^{-1} resulted in the highest mean value of acidity in fruits juice. The plants fertilized with the highest levels of P and K produced fruits having the lowest titratable acidity percentage. The interaction of plant distance by P-K fertilization treatments had significant influences on N, P and K concentration in leaves and fruits. The most effective treatment combination was that of the narrow spacing with 60 and 24 kg of P_2O_5 and K_2O fed^{-1}, respectively, for leaf N concentration and the wide spacing with 90 and 72 kg of P_2O_5 and K_2O fed^{-1}, respectively, for leaf P and K%. Values of N and P % in tomato fruits were the highest under wide spacing with 60 and 24 kg of P_2O_5 and K_2O fed^{-1} and 90 kg P_2O_5 + 72 kg K_2O fed^{-1}, respectively. K concentration in tomato fruits recorded the maximum magnitude as a result of planting at the narrow spacing and fertilizing with 60 and 72 kg P_2O_5 and K_2O fed^{-1}. A higher N uptake in fruits was obtained from the intensive planting, at any level of P; whereas increasing K level depressed fruits N uptake. However values of N uptake were in a decreasing order with 30, 60 and 90 kg P_2O_5, irrespective of K level. P uptake in tomato fruits was significantly higher with intensive than low plant density. At any level of P, increasing K level decreased P uptake. growing tomato plants at 20cm, significantly stimulated the use efficiency of NPK than at 40cm. Use efficiency of N, P and K reached the maximum with the applications of 30 kg P_2O_5 fed^{-1} and 24 kg K_2O fed^{-1} together, and decreased with increasing fertilization level. When tomato plants spaced 20cm and provided with 30 kg P_2O_5 and 72kg K_2O fed^{-1}, use efficiency of N, P and K reached the maximum.

INTRODUCTION

Tomato (*Lycopersicon esculentun*, Mill.) is one of the most important and popular vegetable crops in Egypt. Increasing productivity and quality of tomato crop can be achieved through expanding the cultivated area, especially at the newly reclaimed soils as Nubaria region and /or improving the cultural practices. The area devoted for tomato crop, during the summer season in the newly reclaimed soils at Nubaria region increased to 27300 fed. Most of this area (around 88.9%) is calcareous due to the presence of $CaCO_3$.The carbonates, due to their relatively high solubility, reactivity and alkaline character,buffer the pH of most calcareous soils within the range of

7.5 to 8.5. The presence of $CaCO_3$ in the calcareous soils affects their physical properties such as soil-water availability to plants and soil surface crust. Carbonates, directly or indirectly, affect the chemistry and availability of N, P, K, Mg, Mn, Zn, Cu, and Fe (Obreza *et al.*; 1993 and Marschner, 1995). Although, soils of Nubaria region generally, have a high P content, tomato growers still feel that larger amounts of P fertilization, than the recommended ones, are required to insure perceived fertilization- related reductions in yield and quality or to maintain soil P reserve at a high level. This philosophy is consistent with the 'buildup and maintenance' approach to soil fertility (Fixen and Grove, 1990). Abd-El-Hadi, *et al.* (1990 and 1998) found that addition of potassium to Egyptian soils increased the production of most crops, and plants, greatly, improved the retention of water in the plant tissues even under conditions of severe water stress. Amer (1995) concluded that sand content was the main modifier for exchangeable K critical level, which increased from 200 mg kg^{-1} for soils having more than 85% sand to 500 mg kg^{-1} for those containing 85-45% sand. Etman (1991) reported enhancing effects on yield potential of tomato (total fruit yield and average fruit weight) and fruit quality (total soluble solids and vitamin C contents) as a result of increasing NPK rate. Likewise, Hartz et al. (1999) clarified that the influence of K nutrition on total soluble solids content of tomato fruits was positive. Plant density has been recognized as a vital step in stepping up yield and quality of tomato.

Gupta and Shukla (1977), and Bhatnagar and Pandit (1979) concluded that the closest the spacing, the highest were the marketable tomato fruits yield. Hassan et al. (1982) reported that increasing plant density, significantly, increased total and first grade yields of tomato but early yield was not affected. Likely, results of Mohamedin (1983) and Midan et al. (1985) indicated improving effect on total tomato fruits yield per unit area with the narrow spacing compared to the wide one. El-Fadaly (1991) reported that the maximum marketable and total fruit yields were obtained when tomato plants were planted at 100×20 cm, while the best early yield was recorded at 80×20 cm. Etman (1991) exhibited that decreasing spacing between tomato plants led to reductions in average fruit weight and vitamin C and titratable acidity contents.

The present study was undertaken in order to asses the effects of two plant spacing and P-K fertilization treatments on vegetative growth parameters, yield and yield components and fruit quality of tomato plants grown under calcareous soil conditions. In addition, the plant elemental content, uptake and use efficiencies of N, P and K were considered.

MATERIALS AND METHODS

The present investigation was conducted at the experimental farm, Nubaria Horticultural Research Station, North Tahrir, during the fall seasons of 2000 and 2001. The experimental site belongs to the newly reclaimed calcareous soils irrigated by the surface irrigation system. Preceding the initiation of the investigation, in each season, soil samples from the upper layer of the experimental site to 20 and 20-40cm depth were collected and analyzed for some chemical, physical properties according to the published procedures (Page, 1982 and Klute, 1986). Results of analyses are shown in Table (1). It was a deep sandy clay loam and has a medium permeability while it was a well drained.

Table 1. Some soil chemical, physical and nutritional characteristics of the experimental site in the two growing seasons.

Characteristics	Growing Seasons			
	2000		2001	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
EC; dS m^{-1}	1.52	1.85	1.75	2.05
pH (1:2.5 soil: water)	8.25	8.19	8.15	8.10
OM; %	0.55	0.39	0.45	0.35
$CaCO_3$; %	26.5	28.05	28.20	29.35
$NO_3 + NH_4$; mg kg^{-1}	39.80	48.50	30.28	33.51
$NaHCO_3$-P; mg kg^{-1}	13.30	10.65	12.12	11.52
Exch.-K, mg kg^{-1}	395.50	320.50	325.50	298.50
Sand; %	85.5	84.3	83.5	85.3
Soil texture class	SCL	SCL	SCL	SCL

SCL= sandy clay loam

Tomato seeds cv. Castlerock were sown in the nursery on May 2, 2000 and May 4, 2001. Thirty-five days, after seed sowing, the seedlings were transplanted into the field on one side of rows at two different spacings; 20 and 40 cm between seedlings. Nine fertilization treatments representing all the combinations of three P fertilizer levels (30, 60 and 90 kg P_2O_5 fed^{-1}) and three potassium fertilizer levels (24, 48 and 72 kg K_2O fed^{-1}) were applied. There were 18 treatment combinations in total. Calcium Super phosphate (15.5 % P_2O_5) and Potassium sulphate (48% K_2O) were the respective P and K sources. A seasonal total of 70 kg N fed^{-1} in form of ammonium nitrate (33.5% N) was, also, applied. Application of N, P and K fertilizers were as follow; 1/3 N + 2/3 P_2O_5 after 3 weeks of transplanting, 1/3 N + 1/3 P_2O_5 + 1/2 K_2O at the beginning of flowering and 1/3 N + 1/2 K_2O just after fruit setting.

The experimental design used was a split-plot system in a randomized complete blocks design, with three replications. The main contained the two spacings between plants, while the sub-plots were allocated to P-K fertilization treatments. The experimental unit contained two rows; 5m long and 0.9m wide, the sub plots were separated by two guard rows. All agromanagments necessary for tomato production were followed.

During the growing season the following data were recorded:

1. Vegetative growth characters

Eight weeks after transplanting, plant height was measured from the ground level to the terminal growing point and numbers of branches per plant were counted.

2. Yield and yield components

Tomato fruits of ten plants, randomly chosen from the center of the sub-plot, were harvested at 5 days intervals, starting from 10^{th} and 15^{th} August in 2000 and 2001, orderly. The following data were considered:

a. Early yield (the first three pickings) fed^{-1},

b. Total yield,

c. Average fruit weight using total weight and number of fruits in each picking.

3. Fruit quality

A random sample of fruits was chosen from each treatment at the 3^{rd} picking to determine the following: titratable acidity, total soluble solids (TSS), vitamin-C content; as outlined in A.O.A.C. (1984). Percentage of dry matter, as well, was calculated after drying fruits at 70 °C in a forced-air oven.

4. Chemical composition

Leaf samples from four randomly chosen plants after 80 days of transplanting, and fruit samples taken from the 6^{th} picking were dried and ground for chemical determinations. The dried leaves and fruits samples were wet digested using sulfuric acid and hydrogen peroxide (FAO, 1980). Nitrogen, phosphorus and potassium concentrations were determined according to Westerman (1988) using Vapodust 50 nitrogen distillation unit, spectrophotometer 21D and Jenway flame photometer, respectively.

5. Uptake of N, P and K in tomato fruits

The following formulas were applied to calculate uptake of N, P and K

N, P, K uptake =

Fruit N, P, K concentration (%) × fruit dry matter (kg fed^{-1})

6.Use efficiency of N, P and K fertilizers (UE)

The following formulas were applied to calculate use efficiency (UE) of N, P and K

NUE, PUE, KUE =

Fruits yield (kg fed^{-1}) ÷ N, P, K applied level (kg fed^{-1}),

7.Accumulation efficiencies of N, P and K fertilizers (AE)

N, P and K fertilizers accumulation efficiencies in fruits NAE, PAE and KAE was calculated as:

NAE, PAE, KAE =

Fruits N, P, K uptake (kg fad^{-1}) ÷ N, P, K applied level (kg fed^{-1})

Appropriate analyses of variance were performed on the data of each experiment and over the two experiments using MSTAT-C software (Freed, 1988). Comparisons among means of the different treatments were carried out, using Duncan's multiple range test as illustrated by Gomez and Gomez (1983).

RESULTS AND DISCUSSION

1. Vegetative growth characters

The data concerning the effects of spacing and P-K fertilization treatments on the vegetative growth of tomatoes are presented in Table (2). The results showed that the increase of distance between tomato plants from 20 to 40 cm was not associated with a corresponding increase in the averages of either plant height or number of branches plant^{-1}. There was a slight increase in plant height due to the wide spacing; it did not appear to be an effective factor in this respect. The obtained results, in general, were in a line with Gupta and Shukla (1977), Etman (1991) and Fontes and Fontes (1993).

The responses of plant height and number of branches to its various P-K fertilization treatments did not reflect any significant differences (Table, 2).

Table 2. Effects of spacing and P-K fertilization treatments on vegetative growth of tomato plants during the fall seasons of 2000 and 2001.

PK! Treat-ments	2000			2001			Combined 2 years		
	D 1¶	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
	Plant Height (cm)*								
$P_{30}K_{24}$	45.93a	45.88a	45.91A	50.42aba	42.33de	46.37A	48.17ab	44.11bc	46.14A
$P_{30}K_{48}$	44.57a	44.25a	44.41A	46.42a-e	43.32de	44.87A	44.49abc	43.78bcd	44.64A
$P_{30}K_{72}$	44.33a	43.57a	43.95A	44.67b-e	44.27cde	44.47A	44.50abc	43.92bc	44.21A
$P_{60}K_{24}$	46.33a	52.37a	49.35A	49.17a-d	43.77cde	46.47A	47.75abc	48.07ab	47.91A
$P_{60}K_{48}$	36.08a	46.72a	41.40A	40.25e	46.12a-e	43.18A	38.17d	46.42abc	42.29A
$P_{60}K_{72}$	42.67a	43.17a	42.92A	45.67a-e	51.48ab	48.57A	44.17bc	47.32abc	45.74A
$P_{90}K_{24}$	50.00a	43.35a	46.67A	44.17cde	46.62a-e	45.39A	47.08abc	44.98abc	46.03A
$P_{90}K_{48}$	43.15a	48.07a	45.61A	45.35a-e	52.10a	48.72A	44.25bc	50.08a	47.17A
$P_{90}K_{72}$	42.07a	48.23a	45.15A	42.48de	45.37a-e	43.92A	42.27cd	46.80abc	44.54A
Mean	43.90B	46.18A	44.93A	45.40A	46.15A	45.77A	44.54A	46.16A	45.40A
	No. Branches Plant^{-1}								
$P_{30}K_{24}$	5.00a	5.33a	5.17A	4.33a	4.33a	4.33A	4.67a	4.83a	4.75A
$P_{30}K_{48}$	5.00a	4.00a	4.5A	5.00a	4.67a	4.83A	5.00a	4.33a	4.67A
$P_{30}K_{72}$	4.67a	4.67a	4.67A	4.33a	3.33a	3.83A	4.50a	4.00a	4.25A
$P_{60}K_{24}$	4.67a	6.67a	5.67A	5.00a	5.33a	5.17A	4.83a	6.00a	5.42A
$P_{60}K_{48}$	5.33a	5.33a	5.33A	5.67a	5.00a	5.33A	5.50a	5.17a	5.33A
$P_{60}K_{72}$	5.00a	4.67a	4.83A	4.33a	4.33a	4.33A	4.67a	4.50a	4.58A
$P_{90}K_{24}$	4.67a	4.00a	4.33A	4.00a	3.67a	3.83A	4.33a	3.83a	4.08A
$P_{90}K_{48}$	5.00a	3.67a	4.33A	5.33a	4.00a	4.67A	5.17a	3.83a	4.50A
$P_{90}K_{72}$	4.33a	5.33a	4.83A	4.67a	6.33a	5.50A	4.50a	5.83a	5.17A
Mean	4.85A	4.85A	4.85A	4.74A	4.56A	4.65A	4.80A	4.70A	4.75A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

***Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level**

The interaction effects of spacings with P-K fertilization treatments was found significant on plant height and insignificant on number of branches plant^{-1}. Planting tomato seedlings at 40 cm and with the application of 90 kg P_2O_5 +48 kg K_2O appeared to be the most favorable integrated treatment, which resulted in the longest plants.

2. Yield and its components

Planting tomato transplants at 20 cm, significantly gave greater early and total yield than at 40 cm (Table, 3). The reverse was, however, true for average fruit weight. According to the combined analysis of results, the increments in early and total yield at 20 cm over those at 40 cm were 54.6 and 23.3%, respectively; whereas the reduction in fruit weight was 7.9% indicating that the increase in the plant population per unit area was more than to compensate the decrease in average fruit weight. Therefore, the narrow spacing appeared more productive than the wider spacing. A general agreement was noticed between these results and those reported by many investigators, such as Bhatnagar and Pandita (1979), El-Fadaly (1991), and Smith *et al.* (1992).

Table 3. Effects of spcing and P-K fertilization treatments on total yield and its components of tomato plants during the fall seasons of 2000 and 2001.

PK[!] Treat-ments	2000			2001			Combined 2 years		
	D 1[¶]	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
	Early Yield (ton fed^{-1})*								
$P_{30}K_{24}$	7.89a	4.82fg	6.36A	6.99b	1.79k	4.38DE	7.44a	3.30g	5.37AB
$P_{30}K_{48}$	7.73ab	4.85fg	6.29A	5.35bc	4.43gh	5.39BC	7.04a	4.64de	5.84A
$P_{30}K_{72}$	5.33ef	3.11hi	4.22E	6.02cd	5.63cde	5.83AB	5.67bc	4.37ef	5.02BC
$P_{60}K_{24}$	7.18abc	4.80fg	5.99AB	6.94b	3.93hi	5.43B	7.06a	4.36ef	5.71A
$P_{60}K_{48}$	5.41ef	3.42h	4.41DE	5.49def	3.11j	4.30E	5.45bc	3.26g	4.36D
$P_{60}K_{72}$	6.34cde	3.98gh	5.16CD	4.94efg	3.59ij	4.27E	5.64bc	3.79fg	4.71CD
$P_{90}K_{24}$	6.64bcd	3.51h	5.08CD	8.08a	4.06hi	6.07A	7.36a	3.79fg	5.58A
$P_{90}K_{48}$	7.27abc	2.23i	4.75CDE	4.84fg	4.96efg	4.89CD	6.05b	3.59g	4.82CD
$P_{90}K_{72}$	4.92fg	5.73def	5.32BC	5.59de	5.72cd	5.66AB	5.26cd	5.72bc	5.49AB
Mean	6.52A	4.05B	5.29A	6.14A	4.14B	5.14A	6.332A	4.09B	5.21A
	Total Yield (ton fed^{-1})								
$P_{30}K_{24}$	27.46abc	12.57j	20.02E	30.68a	18.53de	24.60A	29.07a	15.55g	22.31A
$P_{30}K_{48}$	25.86cd	17.31h	21.59CD	25.01b	20.53cd	22.77AB	25.44b	18.92ef	22.18A
$P_{30}K_{72}$	22.25f	18.03gh	20.14DE	24.14b	24.22b	24.18A	23.19c	21.12d	22.16A
$P_{60}K_{24}$	26.48bcd	19.51g	22.99BC	24.45b	17.03e	20.74CD	25.46b	18.27f	21.87A
$P_{60}K_{48}$	19.49g	19.16gh	19.32E	19.88cde	18.74de	19.31D	19.68def	18.94ef	19.31A
$P_{60}K_{72}$	29.50a	18.50gh	24.00B	20.81cd	18.88cde	19.84D	25.15b	18.69f	21.92A
$P_{90}K_{24}$	28.11ab	23.37ef	25.74A	19.96cde	18.20de	19.08D	24.04bc	20.79de	22.41A
$P_{90}K_{48}$	17.64gh	12.08j	14.86F	24.52b	17.57de	21.05BCD	21.08d	14.82g	17.95A
$P_{90}K_{72}$	15.05i	24.74de	19. 90E	22.03bc	24.58b	23.30AB	18.54f	24.66bc	21.60A
Mean	23.54A	18.36B	20.95A	23.50A	19.81B	21.65A	23.52A	19.08B	21.30A
	Fruit Weight (g)								
$P_{30}K_{24}$	74.46cd	74.91cd	74.69C	74.49a	85.06a	79.77A	74.48a	80.00a	77.23A
$P_{30}K_{48}$	82.21a-d	83.58abc	82.89AB	69.12a	80.58a	74.85A	75.66a	82.08a	78.87A
$P_{30}K_{72}$	75.42cd	91.25a	83.34AB	75.58a	84.47a	80.02A	75.50a	87.86a	81.68A
$P_{60}K_{24}$	77.44bcd	72.68d	75.06C	75.45a	77.14a	76.30A	76.44a	74.91a	75.68A
$P_{60}K_{48}$	76.76bcd	77.40bcd	77.08BC	79.57a	75.25a	77.41A	78.16a	76.33a	77.25A
$P_{60}K_{72}$	85.68ab	84.15bc	84.91A	67.44a	81.43a	74.43A	76.56a	82.79a	79.67A
$P_{90}K_{24}$	77.61bcd	89.93a	83.77AB	76.43a	85.06a	80.74A	77.02a	87.49a	82.25A
$P_{90}K_{48}$	72.87d	83.75abc	78.31ABC	72.46a	85.46a	78.96A	72.66a	84.61a	78.64A
$P_{90}K_{72}$	78.74bcd	76.22bcd	77.48BC	83.07a	95.01a	89.04A	80.90a	85.62a	83.26A
Mean	77.91B	81.54A	79.73A	74.84B	83.27A	79.06A	76.38B	82.41A	79.39A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

*Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level

The results of Table (3) reflected the significant effects of P-K fertilizer treatments on early and total yields as well as on average fruit weigh. The maximum early and total yields were attained due to the application of 48 kg K_2O+30 kg P_2O_5 and 24 kg K_2O+90 kg P_2O_5 fed^{-1} orderly. The enhancing effects on early and total yields due to these particular treatments can be explained on the basis that the amounts of P and K fertilizes applied to the growing plants were comparatively adequate and balanced to face the demands of the growing plants than the other ones. Mengel (1978) and Smith *et al.* (1992) came to a similar conclusion.

The interaction effects between the two spacings and the nine P-K fertilization treatments on early and total yields were found significant (Table, 3). Average fruit weight, however, was not affected. At 20 cm distance between plants, the addition of K at rate of 24 kg K_2O fed^{-1} together with P fertilizer at the rate of 30 kg P_2O_5 fed^{-1}, was superior and associated with the best early and total yields, compared with all other treatment combinations.

3. Fruit quality

The comparisons between the means of the two spacing treatments (20 and 40 cm) showed insignificant effects on T.T.S., acidity, vitamin C and dry matter contents of tomato fruits (Tables, 4 and 5).

As a result of using different P-K treatment combinations, titratable acidity of tomato fruits showed some significant differences, but the estimates of T.S.S., Vitamin C and dry matter contents did not reflect any significant differences (Tables, 4 and 5). Fertilizing tomato plants with 60 kg P_2O_5 + 72 kg K_2O fed^{-1} remarked the best treatment combination that attained the highest mean value of titratable acidity in tomato fruits juice. On the other side, the plants fertilized with 90 kg P_2O_5 + 72 kg K_2O fed^{-1} i.e. the highest levels of P and K produced fruits having the lowest titratable acidity percentage. Moursy *et al.* (1992) concluded that, with increasing K fertilization level from 0 to 50, 100 and 150 kg K_2O fed^{-1} , TSS reflected successive increases. The same trend of data was obtained by Feher (1981) who found that K was favorable for total acidity. Hartz *et al.* (1999), concluded that Potassium nutrition has been linked to tomato quality factors of importance to both paste and peeled products. Juice color and pH were not correlated with soil K availability or plant K status. Soluble solids was correlated with both soil exchangeable K and midseason leaf K concentration. The effects of the interaction between plant distances and P-K fertilization treatments on T.S.S., acidity and vitamin C were found significant (Tables, 4 and 5). On the other hand, fruit dry matter was not significantly affected.

Table 4. Effects of spacing and P-K fertilization treatments on fruits quality of tomato plants during the fall seasons of 2000 and 2001.

PK! Treat-ments	2000			2001			Combined 2 years		
	D 1¶	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
				TSS (%)*					
$P_{30}K_{24}$	5.433a	5.533a	5.483A	5.700a	5.067a	5.383A	5.567ab	5.300abc	5.433A
$P_{30}K_{48}$	6.100a	5.000a	5.550A	5.100a	5.300a	5.200A	5.600ab	5.150abc	5.375A
$P_{30}K_{72}$	4.967a	5.367a	5.167A	5.400a	5.000a	5.200A	5.183abc	5.183abc	5.183A
$P_{60}K_{24}$	4.767a	5.600a	5.183A	4.800a	5.367a	5.083A	4.783c	5.483abc	5.133A
$P_{60}K_{48}$	4.800a	5.667a	5.233A	5.333a	5.467a	5.400A	5.067abc	5.567ab	5.317A
$P_{60}K_{72}$	4.967a	5.867a	5.417A	5.667a	4.967a	5.317A	5.317abc	5.417abc	5.367A
$P_{90}K_{24}$	4.733a	5.167a	4.950A	5.133a	5.167a	5.150A	4.933bc	5.167abc	5.050A
$P_{90}K_{48}$	5.200a	5.500a	5.350A	5.300a	4.933a	5.117A	5.250abc	5.217abc	5.233A
$P_{90}K_{72}$	5.600a	4.900a	5.250A	6.033a	4.967a	5.500A	5.817a	4.933bc	5.375A
Mean	5.174A	5.400A	5.287A	5.385A	5.137A	5.261A	5.280A	5.269A	5.274A
				Acidity (%)					
$P_{30}K_{24}$	0.978def	0.978def	0.978CD	1.081a	0.872a	0.977A	1.030b-e	0.925ef	0.977BC
$P_{30}K_{48}$	1.287ab	1.054cde	1.170B	1.104a	0.822a	0.963A	1.195ab	0.938ef	1.067AB
$P_{30}K_{72}$	0.974def	1.159a-d	1.067BC	1.015a	1.057a	1.036A	0.995cde	1.108a-e	1.051ABC
$P_{60}K_{24}$	1.026def	1.156a-d	1.091BC	1.092a	0.966a	1.029A	1.059b-e	1.061b-e	1.060AB
$P_{60}K_{48}$	0.853fg	0.963ef	0.908D	1.093a	0.947a	1.020A	0.973de	0.955de	0.964BC
$P_{60}K_{72}$	1.340a	1.335a	1.337A	1.004a	0.937a	0.970A	1.172abc	1.136a-d	1.154A
$P_{90}K_{24}$	1.065cde	0.982def	1.024CD	0.929a	0.998a	0.963A	0.997cde	0.990cde	0.994BC
$P_{90}K_{48}$	0.943ef	1.225abc	1.084BC	1.155a	1.281a	1.218A	1.049d-e	1.253a	1.151A
$P_{90}K_{72}$	1.098b-e	0.713g	0.906D	1.077a	0.836a	0.956A	1.087a-e	0.775f	0.931C
Mean	1.063A	1.063A	1.063A	1.061A	0.968A	1.015A	1.062A	1.016A	1.039A
				Vitamin C (mg/100ml juice)					
$P_{30}K_{24}$	42.600a	37.550a	40.075A	36.233a	36.837a	36.535A	39.417abc	37.193c	38.305A
$P_{30}K_{48}$	40.750a	44.283a	42.517A	43.500a	41.167a	42.333A	42.125abc	42.725ab	42.425A
$P_{30}K_{72}$	42.833a	42.833a	42.833A	40.000a	35.500a	37.750A	41.417abc	39.167abc	40.292A
$P_{60}K_{24}$	42.083a	40.083a	41.083A	44.083a	38.417a	41.250A	43.083ab	39.250abc	41.167A
$P_{60}K_{48}$	38.250a	44.233a	41.242A	36.583a	40.000a	38.292A	37.417c	42.117abc	39.767A
$P_{60}K_{72}$	45.500a	41.167a	43.333A	42.667a	38.333a	40.500A	44.083a	39.750abc	41.917A
$P_{90}K_{24}$	37.833a	44.250a	41.042A	39.767a	43.333a	41.550A	38.800bc	43.792b	41.296A
$P_{90}K_{48}$	40.250a	44.233a	42.242A	41.250a	41.500a	41.375A	40.750abc	42.867ab	41.808A
$P_{90}K_{72}$	39.167a	42.667a	40.917A	38.250a	45.750a	42.000A	38.708bc	44.208a	41.458A
Mean	41.03A	42.37A	41.70A	40.26A	40.09A	40.18A	40.64A	41.23A	40.94A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

*Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level.

Table 5. Effects of spacing and P-K fertilization treatments on dry matter content of tomato fruits during the fall seasons of 2000 and 2001.

PK! Treat-Ments	2000			2001			Combined 2 years		
	D 1¶	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
				Fruit dry matter content (%)					
$P_{30}K_{24}$	5.73a	5.77a	5.75A	5.35a	5.64a	5.50A	5.54a	5.71a	5.62A
$P_{30}K_{48}$	6.97a	5.18a	6.07A	5.93a	5.20a	5.56A	6.45a	5.19a	5.82A
$P_{30}K_{72}$	6.06a	4.67a	5.37A	6.15a	4.82a	5.48A	6.11a	4.75a	5.43A
$P_{60}K_{24}$	5.96a	5.64a	5.80A	5.19a	5.62a	5.40A	5.57a	5.63a	5.60A
$P_{60}K_{48}$	6.04a	4.40a	5.22A	5.42a	5.50a	5.46A	5.73a	4.95a	5.59A
$P_{60}K_{72}$	5.79a	5.44a	5.62A	5.16a	4.43a	4.79A	5.47a	4.93a	5.20A
$P_{90}K_{24}$	5.19a	5.19a	5.19A	5.24a	5.27a	5.26A	5.21a	5.23a	5.22A
$P_{90}K_{48}$	6.25a	4.94a	5.60A	5.69a	5.22a	5.45A	5.97a	5.08a	5.53A
$P_{90}K_{72}$	6.73a	4.68a	5.71A	5.68a	4.61a	5.14A	6.21a	4.64a	5.42A
Mean	6.19A	5.11A	5.71A	5.53A	5.59A	5.56A	5.86A	5.41A	5.64A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

*Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level

4. Chemical compositions of leaves and fruits

Data in Tables (6) and (7) showed that the narrow spacing between plants, significantly, increased leaf N concentration; but depressed fruit N concentration compared to the wider spacing.

Table 6. Effects of spacing and P-K fertilization treatments on N, P and K concentration in leaves of tomato plants during the fall seasons of 2000 and 2001.

PK! Treat-ments	2000			2001			Combined 2 years		
	D 1¶	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
				Leaves N Concentration (%)*					
$P_{30}K_{24}$	2.31bc	1.87f-i	2.09C	2.37a	1.89a	2.13D	2.34de	1.88hi	2.11C
$P_{30}K_{48}$	2.71a	1.75hi	2.23C	2.68a	1.79a	2.23BCD	2.69ab	1.77ij	2.23BC
$P_{30}K_{72}$	2.29cd	1.94e-h	2.11C	2.35a	2.00a	2.17CD	2.32de	1.97ghi	2.14BC
$P_{60}K_{24}$	2.80a	2.12c-f	2.45AB	2.77a	2.15a	2.46AB	2.78a	2.14efg	2.46A
$P_{60}K_{48}$	2.03d-g	1.61i	1.82D	2.02a	1.65a	1.83E	2.02fgh	1.63j	1.83D
$P_{60}K_{72}$	2.75a	2.26cd	2.51A	2.77a	2.38a	2.58A	2.76ab	2.32de	2.54A
$P_{90}K_{24}$	2.57ab	1.80ghi	2.18C	2.62a	1.84a	2.23CD	2.59ab	1.82hij	2.20BC
$P_{90}K_{48}$	2.78a	1.77ghi	2.27BC	2.33a	1.85a	2.09D	2.55bc	1.81ij	2.18BC
$P_{90}K_{72}$	2.22cd	2.17cde	2.19C	2.48a	2.22a	2.35ABC	2.35cd	2.20def	2.27B
Mean	2.49A	1.92B	2.21A	2.49A	1.97B	2.23A	2.49A	1.95B	2.22A
				Leaves P Concentration (%)					
$P_{30}K_{24}$	0.43fgh	0.44fgh	0.44CD	0.43fg	0.46efg	0.44C	0.43gh	0.45fg	0.44E
$P_{30}K_{48}$	0.47efg	0.44fgh	0.46CD	0.47ef	0.47ef	0.47BC	0.47f	0.45fg	0.46DE
$P_{30}K_{72}$	0.41h	0.46fgh	0.43D	0.41g	0.47ef	0.44C	0.41h	0.46fg	0.44E
$P_{60}K_{24}$	0.43gh	0.52cde	0.47BC	0.42fg	0.52cd	0.47BC	0.43gh	0.52de	0.47CD
$P_{60}K_{48}$	0.44fgh	0.55abc	0.49B	0.43fg	0.55bc	0.49B	0.43gh	0.55bcd	0.49BC
$P_{60}K_{72}$	0.49def	0.54a-d	0.51B	0.48de	0.52cd	0.50B	0.48ef	0.53cd	0.50B
$P_{90}K_{24}$	0.42h	0.58a	0.50B	0.41g	0.57ab	0.49B	0.42h	0.58ab	0.50BC
$P_{90}K_{48}$	0.55abc	0.55abc	0.55A	0.54bc	0.56abc	0.55A	0.55bcd	0.56bc	0.55A
$P_{90}K_{72}$	0.53b-e	0.57ab	0.55A	0.52bcd	0.61a	0.56A	0.52cd	0.59a	0.56A
Mean	0.46A	0.52A	0.49A	0.46A	0.53A	0.49A	0.46A	0.52A	0.49A
				Leaves K Concentration (%)					
$P_{30}K_{24}$	2.06fgh	2.03fi	2.05E	2.18b-e	2.00e	2.09C	2.12def	2.02fg	2.07D
$P_{30}K_{48}$	2.29abc	2.12ef	2.21C	2.34abc	2.13b-e	2.23BC	2.32ab	2.13def	2.22C
$P_{30}K_{72}$	2.35a	2.32ab	2.34A	2.29abc	2.33abc	2.31AB	2.32ab	2.32ab	2.32AB
$P_{60}K_{24}$	2.01ghi	2.18de	2.09E	2.13cde	2.15b-e	2.14C	2.07efg	2.17cde	2.11D
$P_{60}K_{48}$	2.11efg	2.27a-d	2.19CD	2.23a-d	2.40a	2.31AB	2.17cde	2.34ab	2.25BC
$P_{60}K_{72}$	2.31ab	2.31abc	2.31AB	2.43a	2.34ab	2.39A	2.37a	2.32ab	2.35
$P_{90}K_{24}$	1.96i	2.20cde	2.08E	2.03de	2.26abc	2.14C	1.99g	2.23bcd	2.11D
$P_{90}K_{48}$	2.00hi	2.23bcd	2.11DE	2.00e	2.30abc	2.15C	2.00g	2.27abc	2.13D
$P_{90}K_{72}$	2.19de	2.30abc	2.24BC	2.18b-e	2.42a	2.30AB	2.19cd	2.36a	2.27ABC
Mean	2.14A	2.22A	2.18A	2.20A	2.26A	2.23A	2.17A	2.24A	2.21A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

*Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level

Table 7. Effects of spacing and P-K fertilization treatments on N, P and K concentration in fruits of tomato during the fall seasons of 2000 and 2001.

PK! Treat-ments	2000			2001			Combined 2 years		
	D 1¶	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
	Fruits N concentration (%)								
$P_{30}K_{24}$	2.31bcd	2.22cd	2.26BC	2.40a	2.21a	2.31A	2.35cd	2.21de	2.28BC
$P_{30}K_{48}$	2.17cd	2.33bcd	2.25BC	2.21a	2.43a	2.32A	2.19de	2.38cd	2.29BC
$P_{30}K_{72}$	2.12cd	2.33bcd	2.23BC	2.17a	2.40a	2.28A	2.15de	2.36cd	2.26BC
$P_{60}K_{24}$	2.15cd	2.61ab	2.38AB	2.26a	2.71a	2.48A	2.20de	2.66b	2.43AB
$P_{60}K_{48}$	1.98d	2.24bcd	2.11C	2.00a	2.26a	2.13A	1.99e	2.25cde	2.12C
$P_{60}K_{72}$	2.12cd	2.94a	2.53A	2.20a	2.93a	2.57A	2.16de	2.93a	2.55A
$P_{90}K_{24}$	2.31bcd	2.24bcd	2.27BC	2.40a	2.42a	2.32A	2.35cd	2.24cde	2.30BC
$P_{90}K_{48}$	2.45bc	2.15cd	2.30BC	2.17a	2.20a	2.18A	2.31cd	2.17de	2.24BC
$P_{90}K_{72}$	2.15cd	2.50bc	2.32B	2.17a	2.51a	2.34A	2.16de	2.50bc	2.33B
Mean	2.20B	2.40A	2.30A	2.22A	2.43B	2.33A	2.21B	2.41A	2.31A
	Fruits P concentration (%)								
$P_{30}K_{24}$	0.35de	0.30e	0.32C	0.35a	0.32a	0.33D	0.35gh	0.31h	0.33D
$P_{30}K_{48}$	0.37bcd	0.37bcd	0.37B	0.38a	0.39a	0.38BC	0.37d-g	0.38c-g	0.38C
$P_{30}K_{72}$	0.36cd	0.39a-d	0.38B	0.35a	0.39a	0.37CD	0.36efg	0.39b-f	0.37C
$P_{60}K_{24}$	0.39a-d	0.37bcd	0.38B	0.41a	0.39a	0.40ABC	0.40a-d	0.38c-g	0.39BC
$P_{60}K_{48}$	0.37cd	0.37bcd	0.37B	0.38a	0.37a	0.38C	0.37d-g	0.37d-g	0.37C
$P_{60}K_{72}$	0.41abc	0.39a-d	0.40AB	0.41a	0.43a	0.42AB	0.41a-d	0.41abc	0.41AB
$P_{90}K_{24}$	0.36cd	0.42ab	0.39AB	0.36a	0.45a	0.40AB	0.36fg	0.43a	0.39BC
$P_{90}K_{48}$	0.39a-d	0.40abc	0.40AB	0.40a	0.41a	0.40ABC	0.39b-e	0.40a-d	0.40BC
$P_{90}K_{72}$	0.42ab	0.43a	0.42A	0.42a	0.43a	0.43A	0.42ab	0.43a	0.43A
Mean	0.38B	0.39A	0.38A	0.38B	0.40A	0.39A	0.38A	0.39A	0.39A
	Fruits K concentration (%)								
$P_{30}K_{24}$	3.33i	3.42f-i	3.38E	3.38a	3.26a	3.32C	3.35g	3.34gh	3.35D
$P_{30}K_{48}$	3.43f-i	3.57b-e	3.50CD	3.48a	3.63a	3.55A	3.45d-g	3.60abc	3.53B
$P_{30}K_{72}$	3.52def	3.63a-d	3.58BC	3.36a	3.66a	3.51AB	3.44d-g	3.65ab	3.54B
$P_{60}K_{24}$	3.13j	3.46e-h	3.30E	3.26a	3.45a	3.35BC	3.20h	3.45c-g	3.33D
$P_{60}K_{48}$	3.48efg	3.54c-f	3.51BCD	3.58a	3.53a	3.60A	3.53b-f	3.58a-d	3.55AB
$P_{60}K_{72}$	3.73a	3.64abc	3.69A	3.64a	3.61a	3.62A	3.69a	3.62ab	3.66A
$P_{90}K_{24}$	3.36hi	3.40ghi	3.38E	3.46a	3.45a	3.46ABC	3.41fg	3.42efg	3.42CD
$P_{90}K_{48}$	3.57b-e	3.40ghi	3.48D	3.54a	3.42a	3.48ABC	3.55a-e	3.41fg	3.48BC
$P_{90}K_{72}$	3.68ab	3.49efg	3.58B	3.62a	3.44a	3.53AB	3.65ab	3.64c-g	3.56AB
Mean	3.47A	3.51A	3.49A	3.48A	3.50A	3.49A	3.48A	3.51A	3.49A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

***Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level**

Nevertheless, whether the plant distance was narrow or wide, P and K concentrations in leaves and fruits were not significantly affected. The effects of P-K fertilization treatments on N, P and K concentration in leaves and fruits of tomato reflected significant differences (Tables, 6 and 7). The obtained results, indicated obviously that the application of P and K at the rates of 60 kg P_2O_5 and 72 kg K_2O fed^{-1}, together, was remarkable and resulted in the highest concentrations of P and K in the leaves and fruits of tomato. Increasing P rate to 90 kg P_2O_5 together with the previous rate of K gave the maximum concentration of P in both the leaves and fruits of tomato.

The interaction of plant distance by P-K fertilization treatments had some significant influences on N, P and K concentration in leaves and fruits

(Tables, 6 and 7). The most effective combination treatment was that of the narrow spacing + 60 kg P_2O_5 + 24 kg K_2O fed^{-1} for leaf N concentration and that of the wide spacing + 90 kg P_2O_5 + 72 kg K_2O fed^{-1}, for leaf P and K concentrations. Values of N and P concentrations in tomato fruits were the highest when the plants were transplanted at the wide spacing and supplied with 60 kg P_2O_5 + 24 kg K_2O fed^{-1} and with 90 kg P_2O_5 + 72 kg K_2O fed^{-1}, respectively. K concentration in tomato fruits recorded its maximum magnitude as a result of planting at the narrow spacing and fertilizing with 60 kg P_2O_5 + 72 kg K_2O fed^{-1}. Concentrations of K in leaves reached adequacy levels in all treatment combinations (Locscio *et al.* 1997).

5. N, P and K uptake and accumulation efficiencies of fruits

Results in Fig. (1) illustrate that the higher intensive planting resulted in a higher N uptake in fruits than the lower intensive planting. At any level of P, increasing K level depressed N uptake in fruits, since, the values of N uptake, irrespective of K level, were in a decreasing order with 30, 60 and 90 kg P_2O_5, orderly. These results indicate that tomato plants grown in soils having high $NaHCO_3$-P content can found adequate available P to face their requirements. Therefore, the application of P over a particular level may cause a case of unbalance of fertilization. Similar findings were reported by Hochmuth and Crrijo (1999).

Fig. (2) shows that the P uptake in tomato fruits was significantly higher with intensive than low plant density. At any level of P, increasing K level decreased P uptake. Likewise, at any level of K, increasing P level decreased K uptake. These results illustrated the importance of the balance between P and K elements depending on the soil test and the critical level of response.

Potassium uptake of tomato fruits was comparatively higher under intensive than under low density of planting (Fig., 3). At the low level of P (30 kg P_2O_5 fed^{-1}) increasing K level reduced K uptake. However, at 60 and 90 kg P_2O_5 fed^{-1}, increasing K level augmented K uptake.

Results of fruits N accumulation efficiency (Fig., 4a) indicated that the low planting density decreased NAE comparing with the intensive planting. The data showed significant decreases in NAE with the increase of PK fertilization level. The highest NAE values were observed for the treatments having 30 kg P_2O_5 fed^{-1} and decreased with the increase of P level. Also interaction effects of P-K fertilization showed reduction in NAE with the increase of K level from 24 to 48 and 96 kg K_2O fed^{-1}at the same P level. These results confirmed the importance of basing the fertilizer recommendations on soil testing (Amer 1995).

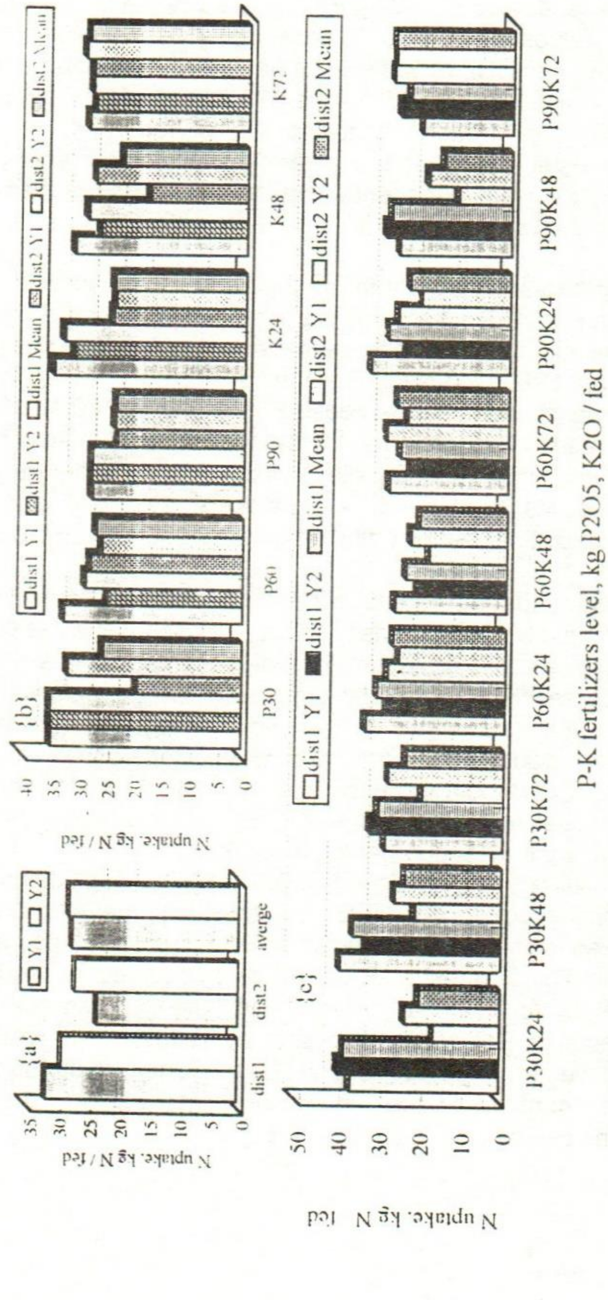

Fig. 1. Effects of different plant dencsites {a}(dist 1= 20cm, dist 2= 40cm) and P-Kfertilization {b} and there interaction {c} on fruits N uptake during the fall seasons of 2000 (Y1) and 2001 (Y2).

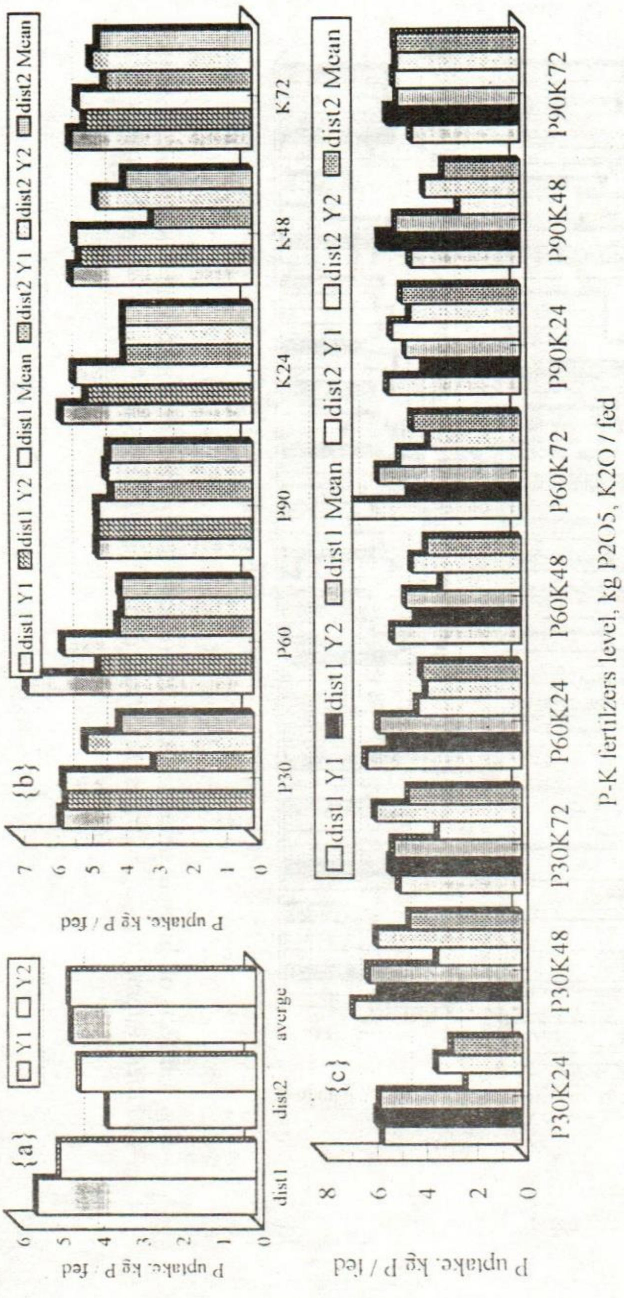

Fig. 2. Effects of different plant denesites {a}(dist 1= 20cm, dist 2= 40cm) and P-K fertilization {b} and there interaction {c} on fruits P uptake during the fall seasons of 2000 (Y1) and 2001 (Y2).

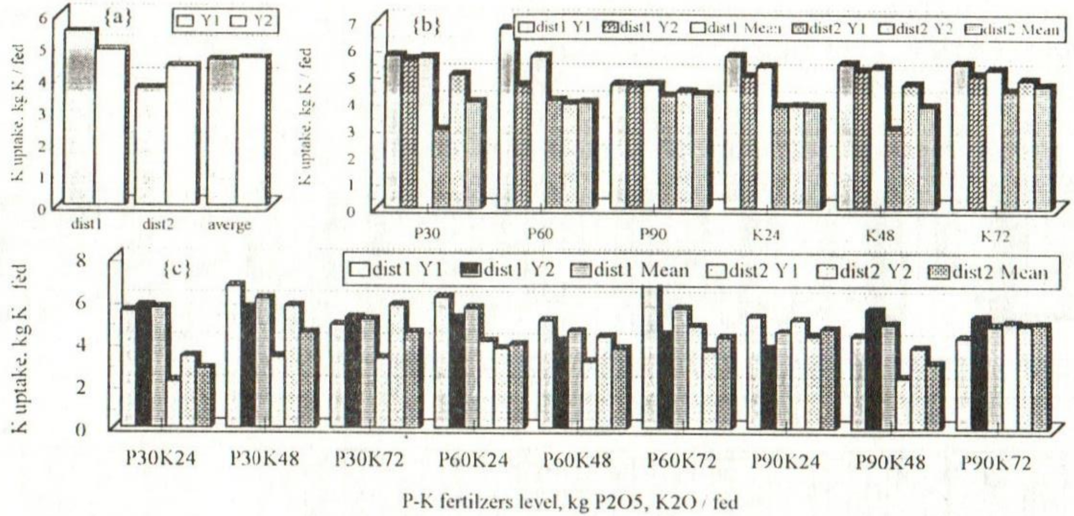

Fig. 3 Effects of different plant denesites {a}(dist 1= 20cm, dist 2= 40cm) and P-K fertilization {b} and there interaction {c} on fruits K uptake during the fall seasons of 2000 (Y1) and 2001 (Y2).

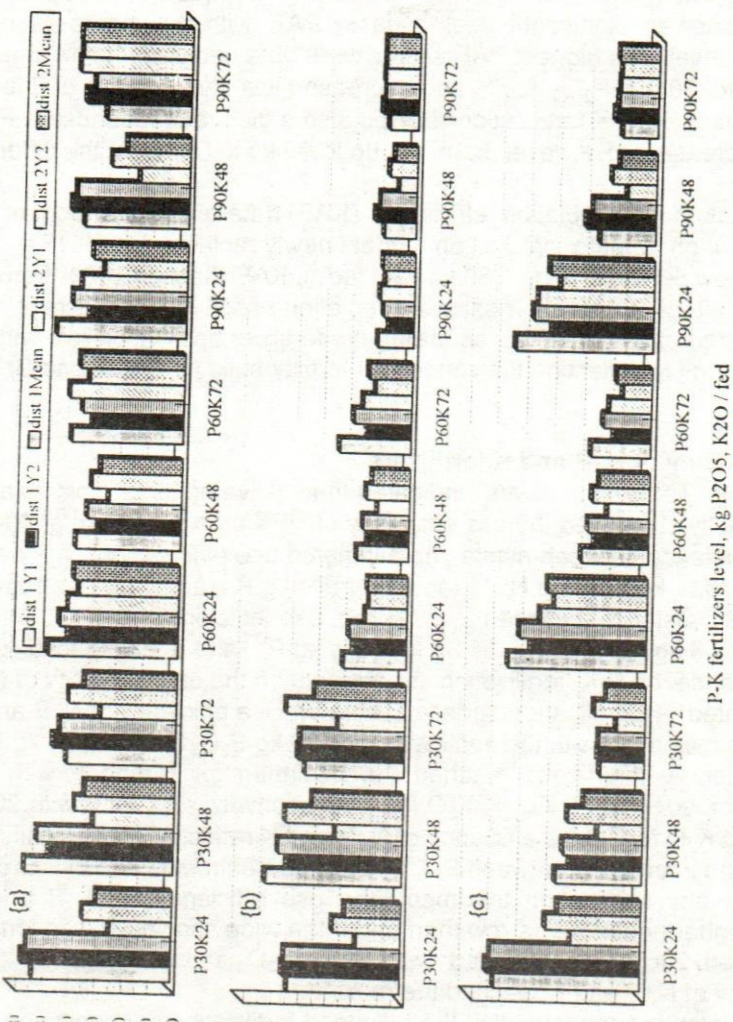

Fig. 4. Effects of different plant distance (dist1=20cm, dist2= 40cm) and P-K fertilization on fruits N, P and K accumulation efficiency(AE) during the fall seasons of 2000(Y1) and 2001(Y2).

Data of fruits P accumulation efficiency (Fig., 4b) indicated that the low density of planting decreased PAE, comparing with the intensive planting. The data showed significant decreases in PAE with the increases of P fertilization level. The highest PAE values were obtained from the treatments that received 30 kg P_2O_5 fed^{-1} and decreased with the increase of P level. The interaction of P-K fertilization showed also a disturbed response in PAE with the increases of K level from 24 up to 96 kg K_2O fed^{-1} at the different levels of P.

Potassium accumulation efficiency (KAE) data reflected importance of K fertilization on tomato production under newly reclaimed lands (Fig., 4c). Under the low K fertilization (30 kg K_2O fed^{-1}), KAE reached 260% from the added amount of K, which means a depletion of soil K; since increasing K fertilization decreased KAE to be near the fertilizer application rate without depletion on soil K, reflecting the concept of fertility build up (Fixen and Grove, 1990).

6. Use efficiency of N, P and K fertilizers

Data in Table (8), clearly indicated that cultivated tomato plants at 20 cm significantly stimulated the use efficiency of NPK than cultivating at 40 cm. At 20 cm distance between plants, the estimated use efficiency of N, P and K averaged 336.0 kg fruits kg N^{-1}, 1140.3 kg fruits kg P^{-1}, and 748.0 kg fruits kg K^{-1}. At 40cm distance between plants, the use efficiency of N, P and K averaged 272.6 kg fruits kg N^{-1}, 881.8 kg fruits kg P^{-1}, and 572.0 kg fruits kg K^{-1}. The influence of P-K fertilization treatments on the use efficiency of N, P and K denoted a significant response (Table 8). Use efficiency of N, P and K reached the maximum with the applications of 30 kg P_2O_5 fed^{-1} and 24 kg K_2O fed^{-1} together, whereas it reached the minimum for N and P with the application of 90+48kg P_2O_5 + K_2O fed^{-1}, respectively; and, for K with 90 kg P_2O_5 + 72kg K_2O fed^{-1}. Use efficiency of N, P and K reflected some significant effects for the interaction between P-K fertilization treatments and by spacing. However, at any fertilization treatment, the use efficiency of N, P and K appeared higher under the narrow than under the wide spacing. When tomato plants spaced 20cm and provided with 30 kg P_2O_5 and 72kg K_2O fed^{-1}, the use efficiency of N, P and K reached the maximum.

These results suggested that the balanced fertilization depending on soil testing and critical levels with the intensive

planting gives the highest return from each of the fertilizers N, P and K units. Whereas under the low density of planting to produce the same tomato fruits yield, more P and K fertilizers should be applied. Potassium nutrition has been linked to tomato quality factors of importance to paste products.

Table 8. Effects of spacing and P-K fertilization treatments on N, P and K use efficiency of tomato during the fall seasons of 2000 and 2001.

PK[!] Treat-ments	000			2001			Combined 2 years		
	D 1[¶]	D 2	Mean	D 1	D 2	Mean	D 1	D 2	Mean
	N Use Efficiency, kg fruits kg N^{-1}								
$P_{30}K_{24}$	392.3abc	179.6j	286.0E	438.3a	264.7fgh	351.5A	415.3a	222.2g	318.7A
$P_{30}K_{48}$	369.4cd	247.3h	308.4CD	357.3b	293.2def	325.3B	363.4b	270.3ef	316.8A
$P_{30}K_{72}$	317.9f	257.5gh	287.7DE	344.8bc	346.0b	345.4AB	331.3c	301.8d	316.5A
$P_{60}K_{24}$	378.3bcd	278.6g	328.5BC	349.2b	243.3h	296.3CD	363.8b	261.0f	312.4A
$P_{60}K_{48}$	278.4g	273.5gh	276.0E	284.0d-g	267.7e-h	275.8DE	281.2def	270.6ef	275.9B
$P_{60}K_{72}$	421.4a	264.3gh	342.9B	297.2de	269.7e-h	283.5CDE	359.3b	267.0f	313.2A
$P_{90}K_{24}$	401.6ab	333.9ef	367.8A	285.1d-g	260.0gh	272.5E	343.4bc	296.9de	320.2A
$P_{90}K_{48}$	252.1gh	172.5j	212.3F	350.3b	251.0h	300.7C	301.2d	211.8g	256.5C
$P_{90}K_{72}$	215.0i	353.4de	284.2E	314.7cd	351.1b	332.9AB	264.9f	352.3bc	308.6A
Mean	336.3A	262.3B	299.3B	336.0A	283.0B	309.3A	336.0A	272.6B	304.3A
	P Use Efficiency, kg fruits kg P^{-1}								
$P_{30}K_{24}$	2094.7a	959.0ef	1536.8B	2340.1a	1413.6cd	1876.8A	2217.4a	1186.3f	1701.8A
$P_{30}K_{48}$	1972.5a	1320.8d	1646.6A	1908.0b	1565.7c	1736.8B	1940.2b	1443.2e	1691.8A
$P_{30}K_{72}$	1697.3b	1375.1cd	1536.2B	1841.1b	1847.2b	1844.2A	1769.2c	1611.2d	1690.2A
$P_{60}K_{24}$	1018.5d	750.2ef	884.4C	940.2d	655.1fgh	797.7C	979.3f	702.7g	841.0B
$P_{60}K_{48}$	749.6ef	736.5ef	743.0D	764.6ef	720.6ef	742.6D	757.1g	728.5g	742.8C
$P_{60}K_{72}$	1134.5c	711.6ef	923.1C	800.3e	726.1ef	763.2CD	967.4f	718.9g	843.1B
$P_{90}K_{24}$	720.8e	599.4f	660.1D	511.8ghi	466.6hi	489.2G	616.3gh	533.0i	574.6D
$P_{90}K_{48}$	452.4g	309.6h	381.0F	628.8efg	450.7i	539.7F	540.6hi	380.1j	460.4E
$P_{90}K_{72}$	386.0gh	634.3ef	510.2E	564.8f-i	630.2efg	597.5E	475.4i	632.3g	553.8D
Mean	1136.2A	821.8B	979.0B	1144.4A	941.7B	1043.1A	1140.3A	881.8B	1011.1A
	K Use Efficiency, kg fruits kg K^{-1}								
$P_{30}K_{24}$	1380.0ab	631.8e	1005.9C	1541.6a	931.3cd	1236.4A	1460.8a	781.6f	1121.2A
$P_{30}K_{48}$	649.7e	435.0fgh	542.4D	628.5e	515.7f	572.1D	639.1g	475.4hi	557.3B
$P_{30}K_{72}$	372.7hi	302.0ij	337.3G	404.3ghi	405.6ghi	405.0F	388.5jk	353.8kl	371.2C
$P_{60}K_{24}$	1330.7b	980.2d	1155.5B	1228.b4	856.0d	1042.2B	1279.6b	918.1e	1098.8A
$P_{60}K_{48}$	489.7f	481.1fg	485.4E	499.5f	470.8fg	485.1E	494.6h	475.9hi	485.3B
$P_{60}K_{72}$	494.1f	309.9ij	402.0F	348.5ij	316.2j	332.4G	421.3ij	313.1l	367.2C
$P_{90}K_{24}$	1412.7a	1174.6c	1293.6A	1003.0c	914.4d	958.7C	1207.8c	1044.5d	1126.2A
$P_{90}K_{48}$	443.3fgh	303.4ij	373.4FG	616.1e	441.5fgh	528.8DE	529.7h	372.5jk	451.1B
$P_{90}K_{72}$	252.1j	414.4gh	333.3G	369.0hij	411.7ghi	390.3FG	310.6i	413.1j	361.8C
Mean	758.3A	559.2B	658.7A	737.7A	584.8B	661.2A	748.0A	572.0B	660.0A

! P levels= 30, 60 & 90 kg P_2O_5 fed^{-1}, K levels= 24, 48 & 72 kg K_2O fed^{-1}

¶ distance 1= 20 cm, distance 2= 40 cm

*Values marked with a common letter within a comparable group of means of the main effects and its treatment combinations are not significantly different using Duncan's multiple range test at 0.05 level

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تأثير التداخل بين الكثافة النباتية و التسميد الفوسفاتي- البوتاسي علـــي إنتاجيــة الطماطم و كفاءة استخدام الأسمدة

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أجريت هذه الدراسة فى تجربتين حقليتين فى الموسم الخريفى لعـــامى ٢٠٠٠، ٢٠٠١ بمزرعـــة محطة بحوث البساتين بالنوبارية تحت ظروف الأراضى الجيرية المســـتصلحة حديثـــا باســـتخدام مســـافتين للزراعة بين النباتات ٢٠ سم، ٤٠سم وتسعة معاملات عاملية عبارة عن جميع التوافيق الممكنة بيـــن ثـــلاث مستويات من التسميد الفوسفات (٣٠، ٦٠، ٩٠ كجم فو٢ أ٥ / فدان) وثلاث مستويات من التسميد البوتاســـى (٢٤، ٤٨، ٩٦ كجم بو٢ أ/ فدان) لدراسة تأثيراتها، وتأثير التداخل بينها على نمو وإ نتـــاج وجـــوده ثمـــار الطماطم (*Lycopersicon esculentun*, Mill.) وكذلك على امتصاص عناصر النتروجين والفوسـفور والبوتاسيوم فى أوراق وثمار الطماطم وتأثير ذلك على كفاءة استخدام النتروجين والفوســـفور والبوتاســـيوم، استخدم فى تنفيذ هذه الدراسة نظام القطع المنشقة فى تصميم القطاعات العشوائية الكاملة بثـــلاث مكـــرارت، حيث وضعت مسافات الزراعة فى القطع الرئيسية، وتم توزيع المعاملات السمادية فى القطع تحت الرئيسية.

يمكن تلخيص أهم نتائج الدراسة فى النقاط التالية:

١. الزراعة على مسافة ٢٠ سم بين النباتات أعطت محصولا مبكرا ومحصولا كليا أعلى مـــن الزراعة على مسافة ٤٠سم.
٢. الزراعة على مسافة ٢٠ سم بـــ ٦٠ كجم فو٢ أ٥ + ٧٢ كجم بو٢ أ أعطى أعلى رقـــم حموضـــة فـــى عصير الثمار وأعلى تركيز للبوتاسيوم فى الثمار.
٣. للتفاعل بين مسافات الزراعة ومستويات التسميد الفوسفاتى - البوتاسى تـــأثير معنـــوى علـــى تركـــيز عناصر النتروجين والفوسفور والبوتاسيوم فى أوراق وثمار الطماطم.
٤. زيادة مستوى التسميد الفوسفورى يزيد من كفاءة امتصاص البوتاسيوم بزيـــادة مســـتوياته بينمـــا يقـــل امتصاص الفوسفور عند تسميده بمعدلات منخفضة تحت ظروف التسميد بمعدلات بوتاسيوم مرتفعة.
٥. الزراعة الكثيفة (على أبعاد ٢٠ سم) زادت من كفاءة استخدام الأسمدة بدرجة أعلى منه عنـــد الزراعـــة على أبعاد ٤٠ سم.
٦. تقل كفاءة استخدام الأسمدة مع زيادة معدلات التسميد لكل عنصر على حده.
٧. عند زراعة الطماطم على مسافة ٢٠ سم والتسميد بمعدل ٣٠ كجم فو٢ أ٥ و٧٢ كجم بو٢ أ فـــإن كفـــاءة استخدام أسمدة الأوزت والفوسفور والبوتاسيوم قد وصلت إلى أعلى قيمة لها تحت ظروف الدراسة.
٨. يجب أن تعتمد التوصيات السمادية لعنصرى الفوسفور والبوتاسيوم على تحليل التربة حتى يمكن اضافـــة المعدل المناسب لاعطاء أعلى إنتاج بأقل تكلفة سمادية.