ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 44(3): 799-817, (2006).

INTERCROPPING POTATO WITH MAIZE
BY

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ABSTRACT

Both emergence and establishment of potato (*Solanum tuberosum L.*) are influenced by high air and soil temperatures predominate during summer months in Egypt. Therefore, providing natural shade by an annual crop e.g. maize (*Zea mays L.*) is frequently used to lessen the harmful effect of high temperature on potato growth. This trials were conducted in 2003 and 2004 at South Tahrir Research Station (Ali-Moubark), El-Bustan region, El-Behaira governorate to evaluate two planting dates of potato intercropped with maize; on the 15th of August (75 days after maize planting) and on the 1st of September (90 days after maize planting); two maize densities; full maize density (two plants per hill, 50 cm apart within a row) and 75% of maize density (one and two plants per hill alternatively), and two treatments of defoliation; defoliation of the basal four leaves at 90 days after maize planting and undefoliation. Maize seeds were planted on June 1st and 3rd during 2003 and 2004 years respectively. Effect of these treatments on growth, yield and yield, components of both crops. Competitive relationships and profitability were studied. Field trials were designed in split- split plot. Results indicated that all the imposed treatments showed yield advantage compared with solid planting. Maximum values of total land equivalent ratios (LERs), total gross return, total net return and profitability were obtained when maize was planted at full density, defoliated, and potato was grown on the 15th of August.

Key words: intercropping, defoliation, maize, potato

INTRODUCTION

The most common advantages of intercropping are the complementary of resource use between the component crops, the improved efficiency use of both space and time, the insurance of system against crop failure, improved efficiency of crop protection and the efficient utilization of resources by plants of different growth habits. In Egypt, potato yields are depressed when the crop is grown as monocrop during the hot months of summer (June, July and August) in order to provide local markets with an early crop. Yield reduction, in this regard, is due to a restriction of tuberization caused by high soil and air temperatures. Such adverse effects of high temperature might be mitigated partly through intercropping of potato with an existing maize crop as a shade crop (Ibrahim, 2000). Another advantage of intercropping and early production of potato, in

Egypt, is to provide an opportunity for growing wheat (*Triticum aestivum* L.), after potato harvest during December instead of growing potato after potatoes (Aly *et al.*, 1993).

Several studies on potato-maize population and their geometrical distribution reported that higher values of total yield and yield components of potato were associated with lower density of maize (Ibrahim, 2000; Shams, 2001). Light intensity influences plant growth and development, often affecting biomass accumulation and distribution. In potato, reduced light intensity enhanced stem elongation, number of branches (Ibrahim, 2000), and biomass partitioning in the vines resulting in production of small and irregular tubers (Sale, 1976 and Menzel, 1985). It also reduced total biomass accumulation in the tubers and resulted in low tuber yield compared with potato grown at high irradiance (Ifenkue and Odurukwe, 1990).

Midmore (1990) observed that heat stress harmful effects on potato growth in the tropics could be reduced by growing potatoes in the shade of other crops. On the contrary, shade reduces the light available for photosynthesis. However, if shading treatment is properly managed, the effect of heat reduction may offset the unfavorable effect of low light intensity (Midmore *et al.*, 1988), and improve yield productivity and tuber size (Kuruppuarachchi, 1990). In this regard, time and duration of potato development in a potato-maize intercrop system and the length of maize crop life cycle are very important factors and would affect potato tuber yield. Therefore, the less the duration of the life cycle of shading crops the more the yield of a potato crop (Batugal *et al.*, 1990; Vander Zaag and Demagante 1990). Intensive shade due to the existence of maize basal leaves in a potato-maize intercrop growing system may inhibit the production of tuberization stimulus in potato (Smith, 1981).

In maize, Khalil (1994) indicated positive correlation between maize plant height and height of the first ear on the stalk. Moreover, a negative correlation between high density of maize plants and total grain yield and yield components Fed^{-1} were reported (Moursi *et al.*, 1970; Shafshak *et al.*, 1998 and El-Douby *et al.* 2001).

Hamada (1972); Salwau and Shams El-Din (1992) and El-Douby *et al.*, (2001) revealed that defoliation of maize leaves below the top-most ear leaf insignificantly reduced grain yield as compared to non defoliating treatment. They added that defoliation of all leaves or those above the top-most ear leaf significantly decreased grain yield in comparison to undefoliation or defoliation the leaves below the top-most ear leaf only. They also concluded that maize grain yield of the undefoliated treatment outyielded that of the defoliated one.

The specific objectives of the present study were to determine the effects of intercropping potato with maize on their plant growth and yield. Moreover, to determine the appropriate time of potato planting, maize plant density and the effect of maize basal leaves defoliation in order to intercrop potato with maize under relatively high temperature conditions for an early potato production in Egypt.

MATERIALS AND METHODS

Two field trials were carried out at the South of Tahrir Research Station, Horticulture Research Institute, on sandy soil under drip irrigation system during 2003 and 2004 years. The objective was to study growth and yield behaviour of potato crop intercropped at two planting dates with maize plants that arranged at two geometrical orientations and subjected to basal leaves defoliation. Soil samples were collected at 0-30 cm depth for chemical analysis. The chemical characteristics of the experimental soil are given in Table 1.

Table (1): Chemical characteristics of the experimental soil at 0 -30cm depth.

Properties	Values
pH	7.83
EC (ds/m)	1.49
Exchangeable (cmol. Kg^{-1})	
Ca^{2+}	10.89
Mg^{2+}	6.26
Na^{+}	6.90
K^{+}	2.30
Anions (cmol. Kg^{-1})	
Hco^{3-}	11.8
Cl^{-}	7.0
$So4^{2-}$	7.55
Mineral nutrients (mg. Kg^{-1})	
N	10
P	12
K	60

The treatments of these trials include:

I-Two plant densities of maize intercropped with potato as follows:

Maize was planted on rows 70 cm apart on one side of the rows a distance of 50 cm apart within a row as follows:

- Two plants per hill (100% density) 24.000 $plant^{-1}$
- One and two plants per hill alternatively (75% density) 18.000 $plant^{-1}$

II- Two treatments of defoliation of maize as follows:

- Defoliating the four basal leaves at_90 days after planting (DAP)
- Without defoliating.

III-Two planting dates of potato intercropped with maize as follow:

- 15^{th} of August (75 days after maize planting).
- 1^{st} of September (90 days after maize planting).

Maize seeds of the hybrid TWC 310 were planted on June 1^{st} and 3^{rd} during 2003 and 2004 years. Potato was seeded with locally produced seeds. Whole seed tubers (28-60 mm) of the Diamont variety were planted in the opposite side of the maize rows and spaced 25 cm within the row.

In addition, check plots of maize were grown as solid and check plots represent the two potato planting dates were planted in the four replications to determine the competitive relationships for both crops and profitability fed^{-1}.

The experimental unit was 10 rows; with six m in length and 70 cm in widths giving a total area 42 m^2 (1/100/fed). Cultural management and disease and pest control programmes of maize and potato crops were followed as recommended by the Egyptian Ministry of Agriculture.

All experimental units received identical amounts of composted animal manure (30m^3 fed^{-1}), and phosphorus (75 kg P_2O_5. fed^{-1}) provided from super phosphate (15% P_2O_5) bounded in rows before planting.

Maize plants received 120 kg N. fed^{-1} in the form of ammonium sulphate (20.6 % N). Nitrogen was added at 10 equal doses; the first dose was added on 15 (DAP) and every 3 days . Potassium sulphate (48-50% K_2O) was added at the rate of 100 kg K_2O. fed^{-1} in two equal doses; the first dose was added on 15 DAP and the second dose was applied on 21 DAP.

150 kg N. fed^{-1} was applied to potato plants in all experimental unit. An amount representing 25% of the total N was base dressed before potato planting as ammonium sulphate (20.6% N). The rest was split equally and applied starting at 35 DAP at intervals for five to six times till 70 DAP. First nitrogen dose was in the form of ammonium sulphate (20.6% N). Whereas other doses were in the form of ammonium nitrate (33.5%N). Potato plants received potassium (96 kg K_2O. fed^{-1}) in the form of potassium sulphate (48-50% K_2O) at planting and at 35-40 DAP in equal amounts.

Data recorded

Maize data

At full growth (100 DAP), ten maize plants from each treatment were taken to determine plant height (cm), height of the topmost ear from the ground (cm), ear length (cm), ear diameter (cm), number of rows ear^{-1}, number of kernels row^{-1} and weight of 100 kernels (g). In addition, at harvest (120 DAP) grain yield in "Ardab" was determined per experimental unit (42 m^2) and consequently yield fed^{-1} (4200 m^2) was calculated. Maize was harvested at 120 DAP allowing potato plants of first and second planting dates to intercrop with maize for 45 and 30 days, respectively. One "Ardab" is equal to 140 kg of shelled grains adjusted to 15.5% moisture content.

Potato data

At 75 DAP, ten potato plants from each treatment were taken to determine plant height (cm), number of branches $plant^{-1}$, number of total tubers $plant^{-1}$, fresh weight (FW) of foliage $plant^{-1}$ (g). At harvest (115 DAP), total tuber yield (g $plant^{-1}$), fresh weight (g $plant^{-1}$) of under-sized tubers (<28 mm), fresh weight (g $plant^{-1}$) of medium-sized tubers (28-60 mm) and fresh weight (g $plant^{-1}$) of over-sized tubers (>60 mm) were determined. The percentage of tuber dry matter (DM) was calculated using medium-sized tubers (28-60 mm) selected from each experimental unit. Total tuber yield fed^{-1} was calculated following the determination of total tuber yield calculated for each experimental unit (42 m^2).

The experimental design was a spilt-split plot design with four replications in both years. Maize densities were the main treatments whereas defoliation treatments of maize and dates of potato planting represented the sub- and sub-sub treatments, respectively.

Data were statistically analyzed according to Snedecor and Cochran (1982). The Fishers protected least significant difference (LSD) at $P \leq 0.05$ was employed to separate the treatment means.

The competitive relationships for both crops during 2003 and 2004 years were calculated.

Competitive relationships

1- **Land Equivalent Ratio (LER)** was described by Mead and Willey (1980) as follows

$$LER = \sum_{i=1}^{n} (Y_i^{I} / Y_i^{M})$$

Where Y_i^{I} = yield of crop i in intercropping
Y_i^{M} = yield of crop i in monocropping,
n = number of crops in the intercropping system

2- **Area Time Equivalent Ratio (ATER)** considers time factor along with land area. It was proposed by Hiebsch McCollum (1987a). It is calculated as

$$ATER = \sum_{i=1}^{n} [(T_i^{M} / T_i^{I}) (Y_i^{I} / Y_i^{M})]$$

Where T_i^{M} = Duration of crop i in monocropping,
T_i^{I} = Total duration of the intercrop system.

3- **Competition Ratio (CR)** is based on yield and space assigned to each species in an intercropping system (Mason *et al.*, 1986). From the definition, the term CR is therefore the ratio of the particular LERs of the two intercrops, but corrected for the sown proportion of either crop (Willey and Rao, 1980). The CR of crop B is the reciprocal of the CR of crop A.

$$CR_A = (LER_A / LER_B) (S_B / S_A)$$

Where: S_A = relative space occupied by crop A
S_B = Relative space occupied by crop B

The profitability fed^{-1} (average of two years) was calculated for each treatment in the Egyptian pounds LE fed^{-1} using the average market prices for both years. The cost of land rental for each crop was calculated as an average of two years. The average market prices was 120 L.E $Ardab^{-1}$ of maize grain and were 900 and 600 LE ton^{-1} of early and late harvested potatoes, respectively. The profitability of each treatment was calculated according to the following formula:
Profitability = {(net benefit/ total variable cost) X 100}

RESULTS AND DISCUSSION

A- The potato crop

1- Effect of maize densities and geometrical distribution

The effect geometrical distribution of maize when intercropped with potato on growth, yield and yield components of potato was statistically significant in all traits in both 2003 and 2004 season, except, in cases of dry matter of tubers (%) and tuber yield fed^{-1} in the first season and the average number of branches $plant^{-1}$ in the second season (Table 2). Data indicated taller potato plants with more branching when maize was associated with potato under higher density (100%). On the other hand the number of total tubers $plant^{-1}$, fresh weight of foliage, the dry matter of tubers (%) and tuber yield fed^{-1} had reversed trends. Higher values of these traits were associated with lower density of the shade crop (75%). These results were also valid in both seasons. the increases in potato height and number of branches $plant^{-1}$ with increasing density of the shade crop might owe much to plant to plant competition for light intercepted by foliage supporting the results obtained by Ibrahim (2000) and Shams (2001), whereas reduction in the values of other traits with increasing maize density up to 100% of its normal population per unit of land could be due to the shading effect of maize plant on plant growth, bulking and tuberization of potato supporting the results obtained by Midmore (1990). He reported that the reduction in irradiance intercepted by potato foliage as a result of natural shading would be expected to favor haulm growth at the expense of tuber growth. The production of stimulus for tuberization and later the efficiency of dry matter partitioning to tubers, may be inhibited by the lower levels of radiation due to canopy over shading before or after the period of tuberization. Sale (1976), reported also that reduced irradiance approximately one half of full sunlight would be expected to decrease CO_2 assimilating rate and the carbohydrate status of potato plant canopy assimilation. The effect of the density of the overstory plants on weight of different tuber sizes was also pronounced. The data indicated that the average fresh weight of tuber with <28mm in diameter as well as those between 28- 60mm in diameter when maize density was 75% was significantly less than those when maize density was 100% of its density. On the other hand, fresh weight of tubers <60mm in diameter when maize shaded potato with its full density was significantly less in weight than when potato shaded with maize at 75% of its full density. Interpretation for this criterion fell heavily upon sun irradiance that reach the understory crop, in particular the more shade provided by two maize plants at each 50cm apart between maize plants in case of the full maize density treatment the less the average fresh weight of tuber < 60mm in diameter. Nevertheless the total fresh weight of tubers $plant^{-1}$ was in favor the 75% maize density treatment indicating superiority of this treatment. These results were also true in both seasons. These results are in agreement with those obtained by Sharaiha (1986); Shafshak *et al.*,(1998); Ibrahim (2000) and Shams (2001). Kuruppuarachchi (1990) reported that large size of potato tubers was much less in the more shaded intercrop association supporting these results.

Table (2): **Effect of maize densities and geometrical distribution on growth, yield and yield components of potato intercropped with maize in 2003 and 2004 seasons.**

Treatment	Maize density			
	2003		2004	
	100%	75%	100%	75%
Plant height (cm)	66.28a	53.07 b	67.09a	52.65 b
No. of branches plant^{-1}	9.39a	8.79 b	9.18a	8.78a
No. of tubers plant^{-1}	7.72 b	8.23a	7.79 b	8.42a
Fresh weight per plant of (g)				
Foliage	111.76 b	129.32a	112.82 b	126.48a
<28mm	31.47a	23.00 b	30.66a	21.91 b
28-60mm	253.01a	238.22 b	246.64a	230.67 b
>60 mm	214.67 b	268.47a	220.43 b	281.97a
Total Tuber	499.15 b	529.69a	497.73 b	534.55a
Tuber yield (t fad^{-1})	9.83a	10.28a	9.63 b	10.50a
Dry matter of tubers (%)	18.91a	19.31a	19.54 b	20.40a

Horizontal means with the same letter within the same year, are not significantly different ($P \leq 0.05$)

2- Effect of defoliated basal four leaves of maize plants

Table (3) showed the effect of defoliating the four lower leaves of maize plants on growth, yield and yield components of potato. The data indicate clearly that the number of tubers plant^{-1}, fresh weight of shoot plant^{-1}, the fresh weight of tubers plant^{-1}, the dry matter of tubers (%), fresh weight and tuber yield fed^{-1} were significantly higher when the shade crop was defoliated as compared with underfoliated maize in the intercrop. These results seemed fairly true in both seasons. Olasantan (1988) and Ifenkue and Odurukwe (1990) explained the reduction in growth, yield and yield components of potato plants as due to reduced irradiance which penetrates to the base crop when maize plants remained without defoliating the lower leaves. On other hand plant height of potato and the average number of branches plant^{-1} when maize plants were left undefoliated were higher than when maize plants were defoliated probably due to depressed photosynthetic rate as a result of detaching the lower four leaves of maize plants. These results are coincided was those obtained by Midmore *et al.* (1988).

Defoliating the shade crop had distinctive pattern on the average weight of different sizes of potato plant^{-1}. The course of change was in resemblance to the effect of plant density of the shade crop. The fresh weight of potato tuber trends with <28mm and between 28- 60mm in diameter when potato plants were shaded with defoliated maize plants were the same when comparing with potato shaded with maize remained undefoliated. The fresh weight of potato tuber plant^{-1} (<28 and between 28-60mm) and maize remained undefoliated were superior to those when maize defoliated in both seasons. These results were true in both seasons. Nevertheless differences, did not reach level of significance in the first season with the medium sized (28-60mm) potato. On the other hand, the weight of large sized potato tubers(>60mm) in diameter were significantly higher in case of potato plant shaded with the defoliated maize plants as compared with potato grown under undefoliated maize plants in both seasons. This contradictory results are cogent and plausible by the hypothesis that potato bulking with larger size was tenaciously correlated with higher light penetration to potato plant, (the understory crop) when maize was defoliated. It is also evident that the total fresh weight of tubers plant^{-1} was associated with defoliated the shade crop indicating that the heavy weight of large tubers could offset the light weight of both small and medium sized tubers when potato was shaded with defoliated maize. These observations seemed valid in both seasons. It could be concluded that there were increases in yield and yield components of potato with diminishing shade intensity as a consequence of defoliated maize plant. Smith (1981) reported that the production of stimulus for tuberization and later the efficiency of dry matter partitioning to tuber might be inhibited by the lower levels of radiation due to canopy over shading before or after the period of tuberization. Menzel (1985), Ibrahim (2000) and Shams (2001) came to similar results.

Table (3): Effect of defoliated basal four leaves of maize plants on growth, yield and yield components of potato intercropped with maize in 2003 and 2004 seasons.

Treatment	2003		2004	
	Defoliated	Unde-foliated	Defoliated	Unde-foliated
Plant height (cm)	51.03 b	68.33a	51.88 b	67.87a
No. of branches plant^{-1}	8.15 b	10.03a	7.92 b	10.00a
No. of tubers plant^{-1}	9.14a	6.90 b	9.18a	7.03 b
Fresh weight per plant of (g)				
Foliage	133.56a	107.52 b	132.82a	106.48 b
<28mm	19.62 b	34.85a	17.65 b	34.92a
28-60mm	243.22a	248.02a	236.70 b	240.61a
>60 mm	271.50a	211.63 b	281.80a	220.59 b
Total Tuber	534.43a	494.50 b	536.15a	496.12 b
Tuber yield (t fad^{-1})	10.15a	9.50 b	10.68a	9.46 b
Dry matter of tubers (%)	10.60a	18.08 b	20.96a	18.98 b

Horizontal means with the same letter within the same year, are not significantly different ($P \leq 0.05$)

3- Effect of planting dates of potato

Data on the effect of date of planting potato on growth yield and yield components of the intercropped potato indicate that the late date (1st of September) was much more favorable for potato yield and its attributes, the number of total tubers plant^{-1}; weight of foliage; the fresh weight of large tubers; total weight of fresh tubers plant^{-1}; the dry matter of tubers (%) and tuber yield fed^{-1} in both seasons (Table 4) Height of potato plants and average number of branches plant^{-1} of early planting date (15th of August) followed a reversal trend indicating that a tendency to more vegetation was associated with the early date of planting potato. From another angle of data, the fresh weight of tuber plant^{-1} which are <28mm or 28-60mm in diameter also followed the same reversal trend.

However, the statistical analysis revealed significant differences between the two dates of planting for all the growth, yield and yield components in both seasons.

Table (4): Effect of potato planting date on growth, yield and yield components of potato intercropped with maize in 2003 and 2004 seasons.

Treatment	Date of planting			
	2003		2004	
	15/8	1/9	15/8	1/9
Plant height (cm)	61.72a	57.63 b	61.07a	58.68 b
No. of branches plant^{-1}	10.63a	7.55 b	10.44a	7.51 b
No. of tubers plant^{-1}	6.50 b	9.54a	6.55 b	9.66a
Fresh weight per plant of (g)				
Foliage	94.23 b	146.85a	92.98 b	146.33a
<28mm	42.34a	12.13 b	40.90a	11.67 b
28-60mm	260.73a	230.51 b	262.46a	214.85 b
>60 mm	158.39 b	324.74a	161.92 b	240.48a
Total Tuber	461.46 b	567.38a	465.28 b	567.00a
Tuber yield (t fad^{-1})	9.00 b	11.10a	9.01 b	11.13a
Dry matter of tubers (%)	17.29 b	20.94a	18.16 b	21.78a

Horizontal means with the same letter within the same year, are not significantly different ($P \leq 0.05$)

4- Interaction effect of maize densities, defoliated the basal leaves of maize plants and potato planting date.

The interaction effect of maize density and defoliated basal four leaves of maize; and date of potato planting also followed the general tendency of the main variables when they behaved individually (Table 5). As a consequence, highest values of yield fed^{-1} was evident when the shade crop diminished its plant density to only 75% of full stand maize and the lower four leaves of maize was defoliated and potato was planted into maize on the 1st of September (the late date). Potato yield fed^{-1} minimized when potato was planted into the shade crop as early as 15th of August under maize plants grown at full density and left undefoliated. Nevertheless differences among the treatment imposed were insignificant even in both seasons. On other hand, significant differences were indicated among the treatment effects on the average number of total tubers plant^{-1} and the total fresh weight of tuber plant^{-1}. However, the treatment effect of these traits followed the same trend as in potato yield of tuber in both seasons. The interaction effects on tuber weight of different size of tuber plant^{-1} were also significant but had distinctive patterns except incase of those tubers with less than <28mm differences were insignificant. Maximum values of fresh weight of tuber <28mm in diameter were when potato was planted on the 15th of August under full density of the shade crop remained undefoliated in both seasons, whereas, minimum values were recorded when potato was planted on the 1st of September and 75% density of defoliated maize in both seasons. The data on fresh weight of medium size of tubers (28-60mm) revealed regular trend. Minimum values of potato grown at the late date under defoliated maize grown at 75% of its full density were evident in both seasons. However, maximum values were associated with the late date of planting potato and when potato was grown under full density of defoliated maize in 2003 season, but, at the earlier date and 75% of maize density remained undefoliated in 2004 season. The data also revealed that the late date of potato planting and potato was grown under 75% of defoliated maize had the maximum weight of potato >60mm in diameter in both seasons. While potato planted on the 15th of August and grown under full density of undefoliated maize had the least values.

B-The maize crop

1- Effect of maize densities

Data in Table (6) indicate clearly that maize density had different effects on growth, yield and yield components of maize plants in both seasons. Plant height and height of top most ear were insignificantly greater when maize population was at its full density than when diminished to only 75% of its full density. These results are in agreement with those obtained by Ibrahim (2000) and El-Douby *et.al.* ,(2001). This tendency might be due to plant to plant competition for light intercepted by foliage which in turn led to increases in length of stem internodes. Plant configuration density added supportive evidence to this result; the more the shade associated with the two plants hill^{-1}, the higher maize plants were observed (the full maize density treatment). The effect of maize density on height of top most ear followed the same pattern as in case of plant height. It seemed that both traits were associated with each other. The results were also supported by Khalil (1994). The effect of maize density on ear length, ear diameter, number of rows ear^{-1}, number of kernels row^{-1} and 100-grain weight was regular in both seasons. The data indicated that all values of these traits when maize was grown at 75% of its full density were higher than when maize plants were grown at its full density. Nevertheless significancy only occurred in case of ear diameter in both seasons, in the second season in case of ear length, and in the first season in case of number of kernels row^{-1}. These results were supported by several workers such Sutater *et al.*, (1986) who interpreted the increases in the values of these traits with decreasing plant density of maize plants as due to lesser intra specific competition between plants. Khalil (1994), Ibrahim (2000) and Shams (2001) came to similar results.

The grain yield of maize fed^{-1} behaved the reverse to yield component traits. Yield of grain when maize was at its full density significantly exceeded that when maize plants were orientated at 75% of its full density. These results were fairly true in both seasons. The excesses were estimated to 16.32 and 29.30% over the maize grown with lower density in 2003 and 2004 seasons, respectively. However these results were also supported by Olasantan (1988) who interpreted the reduction in maize yield in the association as to be largely attributed to a reduction in population rather than to a fierce interplant competition for growth resources. These observations were also in agreement with those obtained by Shafshak *et al.* (1998); Ibrahim (2000) and Shams (2001).

Table (5): Interaction effect of maize densities, defoliated the basal leaves of maize plants and potato planting date on growth, yield and yield components of potato intercropped with maize in 2003 and 2004 seasons

Characters / Treatments		Date of planting	Plant height (cm)	No. of branches Plant^{-1}	No. of tubers plant^{-1}	Fresh weight per plant of: Foliage (g)	Tubers (g): <28 mm	Tubers (g): 28-60 mm	Tubers (g): >60 mm	Total (g)	Tuber yield (t fad^{-1})	Dry matter of tubers (%)
2003												
Maize density 100%	Defoliation	15/8	64.00	9.23	7.20	95.07	35.87	255.50	169.00	460.37	9.20	17.72
		1/9	52.40	6.60	10.17	150.47	11.10	278.20	299.77	589.07	11.70	21.67
	Undefoliation	15/8	75.53	11.23	5.53	74.97	62.10	255.57	100.90	418.57	8.30	16.90
		1/9	73.20	8.10	7.97	126.53	16.80	222.77	289.00	528.57	10.10	19.36
Maize density 75%	Defoliation	15/8	46.60	9.87	7.47	117.13	23.00	255.93	206.33	485.26	9.50	18.85
		1/9	41.10	6.90	11.73	171.57	8.50	183.23	410.90	602.63	12.00	22.35
	Undefoliation	15/8	60.73	12.20	5.80	89.73	48.40	275.90	157.33	481.63	9.00	15.67
		1/9	63.83	8.60	8.30	138.83	12.10	237.83	299.30	549.23	10.60	20.38
LSD 0.05			NS	NS	0.47	NS	NS	16.07	5.24	3.23	NS	0.86
2004												
Maize density 100%	Defoliation	15/8	62.67	8.97	7.10	93.80	32.30	266.00	165.67	463.97	9.30	18.98
		1/9	57.07	6.53	10.23	152.30	11.00	270.47	307.00	588.47	11.50	22.19
	Undefoliation	15/8	75.03	11.4	5.60	80.10	62.67	238.30	119.00	419.97	8.03	16.51
		1/9	73.60	8.20	8.32	125.07	16.67	211.80	290.03	518.50	9.70	20.47
Maize density 75%	Defoliation	15/8	45.50	9.37	7.60	110.53	20.30	251.90	210.33	482.53	9.40	19.75
		1/9	42.27	6.80	11.77	174.63	7.00	158.43	444.20	609.63	12.50	22.93
	Undefoliation	15/8	61.07	12.03	5.90	87.47	48.33	293.63	152.67	494.63	9.30	17.41
		1/9	61.77	8.50	8.40	133.30	12.00	218.70	320.60	551.30	10.80	21.52
LSD 0.05			NS	NS	0.61	1.14	NS	3.45	13.92	4.95	NS	NS

Table (6): Effect of maize densities on yield and yield components of maize intercropped with potato in 2003 and 2004 seasons.

Treatment	Maize density			
	2003		2004	
	100%	75%	100%	75%
Plant height (cm)	242.34a	239.73a	239.21a	236.21a
Top most ear height (cm)	128.50a	122.83a	125.83a	120.58a
Ear length (cm)	19.50a	20.34a	19.35 b	20.29a
Ear diameter (cm)	4.56 b	4.94a	4.17 b	4.64a
No. of row ear^{-1}	13.37a	14.30a	12.36a	13.50a
No. of kernels row^{-1}	39.57 b	42.33 a	36.64a	40.39a
100-grain weight (g)	34.24a	35.49a	33.19a	34.75a
Grain yield ardab fed^{-1}	16.18a	13.91 b	15.62 a	12.08 b

Horizontal means with the same letter within the same year are not significantly different ($P \leq 0.05$)

2- Effect of defoliating the four basal leaves of maize plants

Data in Table (7) indicated that defoliating the basal four leaves of maize tended to diminish both plant height and top most ear height in both seasons although the treatment effect was insignificant. It seemed that the defoliation of the four basal leaves of maize probably inhibits photosynthesis and food stuff translocated to the growing points which in turn inhibit meristamic activities and elongation of stem internodes. El-Douby *et al.* (2001) supported this tendency and also indicated insignificant effect of defoliating the basal leaves on maize height and the top most ear height of maize. The data also indicated that the values of ear length, ear diameter, and number of kernels row^{-1} were statistically higher when maize plants were left undefoliated than when basal leaves of plants were defoliated. On other hand although number of rows ear^{-1} and 100-grain weight followed the same pattern, differences failed to reach the level of significance. The treatment effect on grain yield was not significant in both seasons. Undefoliated maize outyielded the defoliated maize plants. The decreases in grain yield were estimated to 3.39 and 5.07 % in 2003 and 2004 seasons, respectively when maize plants were defoliated. However the reduction in yield could be mainly due to reduction in yield components when maize plants were defoliated. The removal of a part of photosynthic surface of maize plants led to reduction in the amounts of metabolites as well as the elimination of the area of tissues capable of fixing light energy which in turn resulted in a depression in the amounts of metabolites tranlocated to the developing ears, might be the cause and effect. Similar results and interpretations were reported by Moursi *et al.*, (1970), Hamada (1972), Salwau and Shams El-Din (1992) and El-Douby *et al.*, (2001).

4- Effect of planting dates of potato

The effect of date of planting potato on growth yield and yield components fed^{-1} was insignificant in both seasons, except in case of ear diameter (Table 8). However, all values of these traits when potato was planted at the late date (1st of September) tended to be higher than those obtained at the earlier date (15th August). This general tendency could be due to the very slight competition between both components in the association when potato plants delayed to the 1st of September. The excesses in grain yield of maize when potato planting was delayed were estimated to 2.49 and 2.19% in the first and second season, respectively. These results were supported by Shams (2001).

Table (7): Effect of defoliating the four basal leaves of maize plants on yield and yield components of maize intercropped with potato in 2003 and 2004 seasons.

Treatment	2003		2004	
	Defoliated	Unde-foliated	Defoliated	Unde-foliated
Plant height (cm)	240.49a	241.58a	237.25a	238.18a
Top most ear height (cm)	124.50a	126.83a	122.08a	124.33a
Ear length (cm)	19.38 b	20.47a	18.55 b	21.12a
Ear diameter (cm)	4.27 b	5.23 a	4.05 b	4.76 a
No. of row ear^{-1}	13.22a	14.45a	12.87a	13.99a
No. of kernels row^{-1}	39.20 b	42.69 a	37.73 b	41.30a
100-grain weight (g)	33.83a	35.90a	32.58a	35.37a
Grain yield ardab fed^{-1}	14.78a	15.30 a	13.49a	14.21a

Horizontal means with the same letter within the same year, are not significantly different (P≤0.05)

Table (8): Effect of planting dates of potato on yield and yield components of maize intercropped with potato in 2003 and 2004 seasons.

Treatment	Date of planting of potato			
	2003		2004	
	15/8	1/9	15/8	1/9
Plant height (cm)	241.16a	240.92a	237.58a	237.85a
Top most ear height (cm)	125.08a	126.25a	122.75a	123.67a
Ear length (cm)	19.60a	20.24a	19.63a	20.04a
Ear diameter (cm)	4.61 b	4.89 a	4.28 b	4.53 a
No. of row ear^{-1}	13.73a	13.94 a	12.97a	13.07a
No. of kernels row^{-1}	39.98a	41.92a	37.73a	39.30a
100-grain weight (g)	34.59a	35.14a	33.57a	34.38a
Grain yield ardab fed^{-1}	14.86 a	15.23a	13.70a	14.00a

Horizontal means with the same letter within the same year, are not significantly different (P≤0.05)

C- Competitive relationships

Effect of maize densities, defoliated the basal leaves of maize plants and potato planting date on competitive relationships

Data in Table (9) indicated clearly that the RYs of maize when grown at full density in the intercrop was less than the unit indicating that some aggressive pressure on maize plants had occurred mainly due to the geometrical distribution of maize plants in the intercrop which resulted in more plant to plant competition and interspecefic competition between both components in the intercrop. These observations seemed valid in both seasons. On the other hand, values of the relative yields of potato as influenced by the interaction were mostly higher than the unit indicating yielding capacity higher than solid potato planting probably due to exposure to the higher summer sun irradiance on tuber germination, growth seedling and plant development when potato was left without shading. The observations were also true in both seasons. The combined interaction effects of the three main variables also revealed that while all values of maize RYs when maize was grown at full stand were higher than those when maize was grown at 75% of its full density under same respective effect of other variables, the reverse was true in case of potato RYs in both seasons. However, highest value of maize RYs were obtained when potato was grown at the late date under undefoliated maize grown at full density, whereas, minimum values were obtained when potato was planted at the earlier date under 75% of maize density and defoliated maize in both seasons. RY potato reached maximum when potato was planted into 75% defoliated maize at the earlier date in first season but at the later date in the second season. Minimum RYs were obtained when potato was planted at the later date into maize remained undefoliated and at full density in both seasons.

Data on land equivalent ratio indicate clearly that all the treatment imposed had achieved yield advantage as compared with solid planting of either crop. Total LERs were approximately one fold growing either crop alone when maize was at full density and defoliated and potato was grown on the earlier date (15^{th} of August), but when potato was grown at the late date of same intercrop system ranked the second in both seasons. On other hand, planting potato at the late date into 75% of full maize density and undefoliated obtained minimum total LERs in both seasons.

Data on area time equivalent ratio (ATER) indicate lower values than those recorded on LERs as the time crops remained on land elongated as compared with the crops grown in pure stand either. However, data indicated yield disadvantage of the intercrop treatment when potato was planted at the late date into maize undefoliated and grown at 75% of its density in the second season (0.9). Maximum values of ATER was obtained when potato was planted at earlier date into defoliated maize grown at full density coincided with the conclusion of Hiebsch and McCollum (1987b) who reported that both area and time factors have to be considered to quantify resources use efficiency in multiseasonal intercrop.

Data on the mean value of LER + ATER also revealed similar trends to both LER and ATER as influenced by the intercropping patterns within each system. Although the trend resembled land equivalent ratio as will as area time equivalent ratio the values mediated both LER and ATER at the same receptive interaction treatment. LER considers only the area factor to estimate intercrop advantage, whereas ATER unrealistically assumes continuous crop growth throughout the year thus it under-estimates the advantage of intercrops. To avoid these problems Balasubramanian and Sekayange (1990) suggested to use the mean values as an arbitrary compromise explaining why values obtained of each interaction treatment were mediated between same respective values of LER and ATER and became more valid.

To estimate the exact degree of competition, the competitive ratio (CR) was calculated. The data indicate that while potato was always more competitive than maize on the average basis of the systems, except, when potato was planted lately under undefoliation 75% and 100% maize density, the trend was reversed in both seasons being higher in the 75% maize treatment.

Table (9): Effect of maize densities, defoliated the basal leaves of maize plants and potato planting date on competitive relationships and yield advantage of potato intercropped with maize in 2003 and 2004

Characters Treatments		Date of planting	yield Maize	yield Potato	Relative yield Ry maize	Relative yield Ry potato	LER	ATER	Mean LER+ ATER	CR Maize	CR potato
					2003						
Maize density 100%	Defo-liated	15/8	15.93	9.20	0.92	1.15	2.07	1.32	1.70	0.80	1.25
		1/9	16.00	11.70	0.93	1.06	1.99	1.14	1.57	0.88	1.14
	Unde-foliated	15/8	16.17	8.30	0.94	1.04	1.98	1.26	1.62	0.89	1.12
		1/9	16.60	10.10	0.96	0.92	1.88	1.09	1.49	1.04	0.96
Maize density 75%	Defo-liated	15/8	13.30	9.50	0.77	1.19	1.96	1.22	1.59	0.86	1.16
		1/9	13.90	12.00	0.88	1.09	1.89	1.08	1.49	0.97	1.02
	Undefoli-ated	15/8	14.03	9.00	0.81	1.13	1.94	1.23	1.59	0.96	1.05
		1/9	14.40	10.60	0.84	0.96	1.80	1.03	1.42	1.17	0.86
Solid			17.23	8.00	-	-	-	-	-	-	-
Solid			-	11.00	-	-	-	-	-	-	-
					2004						
Maize density 100%	Defo-liated	15/8	15.10	9.30	0.90	1.13	2.03	1.29	1.66	0.80	1.26
		1/9	15.50	11.50	0.92	1.06	1.98	1.13	1.56	0.87	1.15
	Undef-oliated	15/8	15.87	8.03	0.94	0.97	1.91	1.22	1.57	0.97	1.03
		1/9	16.00	9.70	0.95	0.89	1.84	1.06	1.45	1.07	0.94
Maize density 75%	Defo-liated	15/8	11.47	9.40	0.68	1.14	1.82	1.16	1.49	0.80	1.26
		1/9	11.90	12.50	0.71	1.15	1.86	1.06	1.46	0.82	1.22
	Unde-foliated	15/8	12.37	9.30	0.74	1.13	1.87	1.19	1.53	0.86	1.15
		1/9	12.60	10.80	0.75	0.99	1.74	0.99	1.37	1.01	0.99
Solid			16.80	8.25	-	-	-	-	-	-	-
Solid			-	10.90	-	-	-	-	-	-	-

D- Profitability

1- Effect of maize densities, defoliated the basal leaves of maize plants and potato planting date on profitability

Data in Table (10) indicate that the gross return obtained from maize reached maximum when maize was grown at its full density and undefoliated and potato was planted on the 1st of September . Whereas minimum value was obtained when maize was grown at 75% of its full density, defoliated and potato was planted on the 15th of August. Gross return from potato behaved the reverse. On other hand, total gross return, total net return and profitability percent behaved regular pattern. Highest values were obtained when potato was planted on the earlier date (15th of August) in defoliated maize grow at full density, whereas, minimum values of gross, net return and profitability were obtained when potato

Table (10): Effect of maize densities, defoliated the basal leaves of maize plants and potato planting date on profitability of potato intercropped with maize mean from two seasons 2003 and 2004

Characters / Treatments		Date of planting	Total variable cost L.E. /fed	Yield: Maize Ardab/fed	Yield: Potato t fa^{-1}	Gross return L.E. /fed: Maize	Gross return L.E. /fed: Potato	Total Gross return L.E.	Total Net return L.E.	Profitability
Maize density 100%	**Defoliated**	**15/8**	4585	15.52	9.25	862.0	8325.0	10187.0	5602.0	1.22
		1/9	4585	15.75	11.60	1890.0	6960.0	8850.0	4265.0	0.93
	Undefoliated	**15/8**	4565	16.02	8.17	1922.0	7353.0	9275.0	4710.0	1.03
		1/9	4565	16.30	9.90	1956.0	5940.0	7896.0	3331.0	0.73
Maize density 75%	**Defoliated**	**15/8**	4500	12.38	9.45	1485.0	8505.0	9990.0	5490.0	1.22
		1/9	4500	12.90	12.25	1548.0	7350.0	8898.0	4398.0	0.98
	Undefoliated	**15/8**	4480	13.20	9.15	1584.0	8235.0	9819.0	5339.0	1.19
		1/9	4480	13.50	10.7	1620.0	6420.0	8040.0	3560.0	0.79
Solid maize			**1480.0**	**17.02**	**-**	**2042.4**	**-**	**2042.4**	**562.4**	**0.38**
Solid potato (15/8)			**3732.0**	**-**	**8.13**	**-**	**7317**	**7317**	**3585**	**0.96**
Solid potato (1/9)			**3732.0**	**-**	**10.95**	**-**	**6570**	**6570**	**2838**	**0.76**

was planted late (1st September) into undefoliated maize grown at full stand. From another angle of date non of the solid cropping system could catch up in gross return, net return and profitability with those obtained from the intercrop. The highest values of gross return, net return and profitability were obtained from potato planted on the earlier date (15th of August) into defoliated maize and grown at full density as an overstory crop exceeded those obtained from maize grown alone by 398.87, 896.09 and 221.05 % and those obtained from potato grown alone by 39.22, 56.26 and 27.08% on the 15th of August and 55.05, 97.39, 60.53% on the 1st of September.

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تحميل البطاطس مع الذرة الشامية

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تؤثر درجات حرارة الجو والتربة المرتفعتين خلال أشهر الصيف في مصـر – على نمو نبات البطاطس. وللتغلب على ذلك يستخدم نبات حولي مثل الذرة الشـامية لتقليل اثر درجات الحرارة العالية على نبات البطاطس وخاصة في بداية عمر النبـات. أجريت تجربتان حقليتان بمحطة البحوث الزراعية بجنوب التحريـر (علـى مبـارك) بمنطقة البستان بمحافظة البحيرة فى موسمى ٢٠٠٣-٢٠٠٤ لدراسة تحميل البطـاطس مع الذرة الشامية تحت تأثير ميعادين لزراعة البطاطس (منتصف أغسطس بعد زراعة الذرة بـ ٧٥ يوم وأول سبتمبر بعد زراعة الذرة بـ ٩٠ يوم) وكذلك كثافتين نبـاتيتين للذرة الشامية ٧٥% من الكثافة الكلية للذرة وذلك بالزراعة على مسافات ٥٠سم بـين الجوز (مع ترك نبات ونباتين بالجورة بالتبادل) و بكثافة قدرها ١٠٠% وذلك بالزراعة على مسافات ٥٠سم بين الجور (مع ترك نباتين بالجورة) ومعاملتين لأزالـه الأوراق من على ساق الذرة وهى توريق الأوراق الأربعة القاعدية من على ساق الذرة الشامية عند عمر ٩٠ يوم من زراعة الذرة وترك النباتات دون توريق. حققت جميع المعاملات ميزة محصولية بالمقارنة بالزراعة المنفردة لكلا المحصولين. وجاءت أعلا قيمة لمعدل كفاءة استخدام الأرض والعائد الكلى والصافي والنسبة المئوية للربحية عندما زرعـت الذرة بكثافة ١٠٠% ونزعت الأوراق السفلى للذرة وزرعت البطاطس فـى منتصـف أغسطس.