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THE EFFICACY OF MICRO-CLIMATE MODIFICATION UNDER INTERCROPPING SYSTEM

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ABSTRACT - The Efficacy of Micro-Climate Modification under Intercropping System
The objective of this field experiment was to study the effect of microclimate modification under intercropping system using two different row arrangements (2:2, 1:2) on the yield of corn (Reward variety) and two potato varieties (Frisia and Berca). Corn and potato yields were increased especially under 2:2 intercropping row arrangement. The increase of potato yield might be related to the reduction in air heat units (by 210 and 28), soil heat units (by 80 and 88), and light interception (by 350 and 344 $\mu mol.m^{-2}s^{-1}$) for "Fisia" and "Berca" varieties, respectively, as compared to their sole crops. Moreover, the values of soil moisture storage (SMS) and evapotranspiration (ET) for "Fisia" tended to decrease under intercropping as compared to sole cropping. While water use efficiency (WUE) of potato "Fisia" under intercropping was significantly higher than under sole cropping. On the other hand, the higher yield of corn under 2:2 intercropping row arrangement when compared to corn sole cropping was related to the higher values of the microclimatic factors. Additionally, planting two potato varieties (Berca and Frisia) in association with corn were efficient when compared to their sole crop, as judged by land equivalent ratio (LER) in all the combination tested.

Key words: microclimate, intercropping, potato, corn, LER

INTRODUCTION

Practicing intercropping system has proved to be more advantageous than sole cropping system. Over the past two decades, intercropping research studies in Jordan, as in many other countries, have led to the description of a number of distinct relationships between the intercropped species. The microenvironmental factors responsible for intercropping yield advantages were not fairly investigated, especially on potato / corn intercropping. However, the results of accumulated information indicated that the efficiency of light use could be an important factor for the yield advantages for both millet / grondnut combination (RADKE AND HAGSTORM, 1976), potato / faba bean (SHARAIHA AND HADDAD, 1986), Okra / peas (SHARAIHA AND HADIDI, 2007). KURUPPUARACHCHI (1990) indicated that the benefits of shading on intercropped potato yields were variable and this variability might be related to the degree of shading. BATUGAL ET AL. (1990) showed that intercropping potato with maize could be beneficial in providing partial shade to the potato and reduce both air and soil temperatures and thus favor tuber production. SHARAIHA AND KLUSON (1994) reported that both air and soil temperatures required for faba been nitrogen fixation were significantly higher when faba bean was planted with peas or with lettuce as compared with its sole crop. FURTHERMORE, JIEMING AND MIDMORE (1990), found that higher yields of corn intercropped with potato were due to higher amount of soil moisture storage caused by the decrease in demand of water after potato maturity. AL- QAHWAJI (1995) mentioned that evapotranspiration for potato and faba bean under intercropping was less than that of sole cropping, while water use efficiency was significantly higher under intercropping than sole cropping. Since the microenvironment under intercropping system depends on many factors such as climate, soil, crops combination and row arrangements, more work of this nature is needed to provide more information and better understanding

of these principles in order to improve intercropping system. Therefore, the objective of this field experiment was to study the effect of the following microclimatic factors: light interception, air and soil temperatures, evapotranspiration, or plant water consumptive use and water use efficiency on the yields of two potato varieties, and corn as they are grown under intercropping and sole cropping.

MATERIALS AND METHODS

An experiment was carried out in Rabba at the Faculty of Agriculture Research Station, University of Mu'tah. The station is located at altitude of 31.2°N, 35.5°E, with an elevation of 920 m above sea level, and 120 km South of Amman. The soil texture is clay loam; the climate is semi-arid with mean annual precipitation of 326mm and mean annual temperature of 16.2°C. Two Potato varieties - *Solanum tuberosum L.* - (Berca and Frisia), and one variety of corn *(Reward) Zea maiz* were planted under two selected intercropping arrangements, that was based on previous study (Sharaiha and Haddad, 1985), in addition to their sole cropping. A randomized complete block design with three replications was used. The treatments included: 1- pure stand of potato"Fisia"variety; 2- pure stand of potato "Berca" variety ; 3- 2:1 potato "Fisia"variety / corn intercropping row arrangement; 4- 2:1 potato "Berca variety / corn intercropping row arrangement; 5- 2:2 potato "Frisia" variety / corn intercropping row arrangement; 6- 2:2 potato "Berca" variety/corn intercropping row arrangement. Each treatment plot consisted of six rows 75cm apart and 4 meters long. Spacing between plants within row was 35cm for potato and 15 cm for corn and bean. Compost poultry manure was applied one week before planting at the rate of 15Mt.ha^{1}. Weeds were kept under control manually. Surface laterals of 16mm diameter were installed on every planting row to deliver water to plants. In line, drippers with 40cm spacing and 4 liters per hour per dripper discharge rate were used for irrigation. The amount of water added was recorded by water flow meter. Soil moisture measurements were taken at 7.5, 22.5, 45 and 75cm soil depth. In addition, gravimetric method was used to support neutron probe readings for the two first layers. Two access tubes (90cm long) of two inches diameter were installed within the row between two adjacent potato and bean plants under intercropping treatments, while one access tube was installed for each sole crop. Calibration for different soil layers was correlated with soil moisture counts of neutron probe with gravimetric soil moisture samples. Linear regression equation for calibration of neutron probe for the third layer was Pv% = 38.30 CR- 22.08 and that for the fourth layer was Pv% = 29.88 CR – 15.23, where Pv% is a volumetric moisture content and CR (count ratio) is a neutron probe reading in the field. Crop evapotranspiration (ET) and soil moisture storage (SMS) were calculated by using the following equations: - ET= R + I + DSi – DP. Where R : is the amount of rainfall and it was = 0, I : is the amount of irrigation, Dsi : is the initial soil moisture content, and DP : is deep percolation and it was = 0. SMS = $\sum$ [increase in soil moisture (+Δ s)]. Where Δs is the difference between two neutron probe readings for the soil moisture storage taken after irrigation by 16 hours and before each irrigation. While water use efficiency (WUE) was calculated by dividing yield over ET. Daily light and temperature (air and soil) measurements (taken between 11AM and 1PM) started 24 days after emergence using porometer and thermometer, respectively. However, temperatures were recorded as heat unit, using the 50-86F method as described by BATTIKHI AND GHAWI, (1987). The heat unit method should indicate which of the treatments provided best temperature for plant growth. Light measurement was taken at the lower, middle and the upper part of the stem (averages were calculated). Harvesting date was on July 10 -11 for potato and corn, while for bean (green pod) started on May 26

– July 9. Yields of the three crops were obtained from the middle three meters of the central four rows, for 2: 2 row combination and from the middle of the central three rows, for 1: 2 or 2: 1 row combinations. The land equivalent ratio (LER) was calculated for the combined intercropped yields and for the intercrop yield of each crop, as described by WILLEY (1979), who expressed the intercrop yield on a relative basis to a sole crop yield (i.e. where LER = 1). Analysis of variance for the micro environmental values and yield data were determined. The Duncan's Multiple Range Test (DMRT) was then employed for means separation.

RESULTS AND DISCUTION

Effect of Air and Soil Heat Units on Yields of Two Potato Varieties under Intercropping with Corn and Sole Cropping.

Table 1, shows the comparison of air and soil heat unit for the two potato varieties "Fisia" and "Berca" grown under sole cropping and intercropping with corn. A reduction of air heat unit with significant differences was observed in the potato intercropping treatments as compared to potato sole cropping treatments. The recorded reduction in air heat unit was 210 and 227 for potato "Fisia" in the 2:2 and 1:2 intercropping row arrangement, respectively. While the recorded reduction in air heat unit was 28 and 224 under the same treatments, respectively. On the other hand, the recorded reduction in soil heat unit was 80 and 151 for potato "Fisia" while for potato "Berca" was 88 and 156 when they were grown with corn under 2:2 and 1:2 row arrangements, respectively. The reduction of both air and soil heat units under intercropped potato were due to the shading effect caused by the accompanied corn crop. However, the significantly higher yield of the two potato varieties were obtained under 2:2 intercropping row arrangement as compared to both potato varieties grown under sole cropping system (Table 1) where the minimum reduction of air and soil heat unit were recorded. Therefore, a certain amount of shading gave optimum air and soil heat units that affected significantly the yield of the two potato varieties. Similar results were obtained by Batugal et al (1990) who showed that the increase in potato yield under potato corn / corn intercropping resulted from the temperature – reducing treatments in comparison with potato sole crop. Moreover, when the two potato varieties were considered within each cropping system namely 2:2 and 1:2 and sole cropping, the air heat units of the intercropped potato "Berca" was significantly higher than that of the intercropped potato "Fisia", while under sole cropping, significant differences did not occur. On the other hand, differences in yield between the two intercropped potato varieties under the same cropping system were insignificant (Table 1). This could be explained by the fact that air and soil heat units requirements were within the range; even though air heat unit in the 2:2 and 1:2 intercropping row arrangements were significantly less than under sole cropping system.

Effect of Air and Soil Heat Units on Yields of Corn under Intercropping with Two Potato Varieties (Frisia and Berca) and Sole Cropping.

When corn was planted with the two potato varieties "Fisia" and "Berca" under 2:2 and 2:1 row arrangements the air and soil heat units were higher than corn sole crop (Table 2). This could attributed to wider spacing between rows as corn was planted in such row

arrangements, where the incident radiation could penetrate through the intercropped corn plants to soil surface. While corn planted as sole crops has a dense canopy and therefore less incident radiation passes through all the leaves along the corn stem. This might explain the higher air and soil heat units obtained under corn intercropping as compared to corn sole cropping. Three hypotheses can be drawn from table 2 when a comparison between the two cropping systems (intercropping and sole cropping). Three hypotheses can be drawn from table 2 regarding both air and soil heat units, in relation to corn yield, were made. The first, when air and soil heat units values were significantly higher under intercropped corn than under sole corn (such as in 2:2 corn potato "Fisia" intercropping row arrangement), the highest significant corn yield was obtained for 2:2 corn potato "Fisia" intercropping row arrangement as compared to the yields obtained in all other treatments (intercropping and sole cropping table 2). The second, when only the air heat unit values were significant higher under intercropped corn than under sole corn plants (such as in 2:2 corn /potato "Berca" and in 2:1 corn potato
"Fisia" intercropping row arrangements), significant higher yields of corn were obtained for the same treatments mentioned above, as compared to sole corn yield, but significant lower yields than 2:2 corn potato "Fisia" intercropping row arrangement. The third, when air and soil heat units values under intercropped corn plants were not significantly different as compared to the values of air and soil heat units under sole corn plants (such as in 2:1 corn /potato "Berca" intercropping), in this case, the corn yields under intercropping and sole cropping were not significantly different. Furthermore, when the two varieties of potato were considered (Fisia and Berca), corn gave significant higher yields with potato"Fisia" than with potato "Berca" (Table 2). This means that potato"Frisia" have had a beneficial effect on corn yield more than potato "Berca" when grown together, due to variety environment (including air and soil heat units) interaction. This fact had been indicated by SHARAIHA (1994), ABU SALEM (1993), CHANDEL ET AL 1987), SHARAIHA (1996).

Effect of Light Interception on Yields of Two Potato Varieties under Intercropping with Corn and Sole Cropping

When the two potato varieties (Fisia and Berca) were planted with corn under dry summer seasons, average light interception by potato was significantly lower than their sole crops (Table 1) due to the shading effect caused by the associated corn plants). A decrease in light interception of 350 and 450 $\mu mol.m^{-2}s^{-1}$ were obtained when potato "Fisia" was grown with corn under 2:2 and 1:2 row arrangements, respectively. While in the case of potato "Berca" the reduction in average light interception was 344 and 508 $\mu mol.m^{-2}s^{-1}$ under the same row arrangements, respectively. However, significant higher yields of the two potato varieties were obtained under 2:2 intercropping row arrangement as compared to their sole cropping (Table 1) where the minimum reduction of light interception were obtained (Table 1). it seems that certain amount of shade play an important role in increasing potato yield production. Similar results were obtained by Kuruppuarachchi (1990), and by Harris (1990). Moreover, average light interception by potato "Berca" was higher than by potato "Fisia" when they were grown under same cropping system (2:2 and 1:2 and sole), the highest significant differences between the two potato varieties were obtained under 2:2 intercropping row arrangement and sole cropping. This could be explained by the differences in their canopy development. However, differences in yield between the two potato varieties under the same cropping system were insignificant (Table 1).
This could be an indication that light interception for both potato varieties under these conditions were within range even if significant differences occurred.

Effect of Light Interception on Yields of Corn under Intercropping with Two Potato Varieties and Sole Croppping

Table 2, shows that corn intercropped with the two potato varieties "Fisia" and "Berca" intercepted more light as compared to corn sole crop. However, significant higher light interception was obtained when corn was planted with the two potato varieties under the 2:2 row arrangement; where it gave an increase in light interception of 62 $\mu mol.m^{-2}s^{-1}$ by corn planted with potato "Fisia", and 94 $\mu mol.m^{-2}s^{-1}$by corn planted with potato "Berca" over the light interception by corn sole crop. While under 2:1 row arrangement, corn plants obtained an increase of 40 and 42 $\mu mol.m^{-2}s^{-1}$ when planted with the two potato varieties "Fisia" and "Berca", respectively, over the value of light interception obtained by corn sole crop. On the other hand, intercropped corn yields were significantly higher than the yield of corn sole crop, with one exception and that when corn was planted with potato "Berca" variety under 2:1 row arrangement, where an insignificant increase of 44% over the yield of corn sole crop (Table 2). The efficient use of light by corn and consequently on its yield, was due to wider spacing between rows, as corn was planted with potato in 2:2 and 2:1 row arrangements. This fact was pointed out by SHARAIHA AND HADIDI (2007) in their work on okra peas intercropping and BATUGAL ET AL (1990) in their study on intercropping potato with maize. MOREOVER, TRENBATH (1976) indicated that a plant with a usually long shoot, such as corn in a dense sole crop would experience an especially unfavorable light regime and lead to a poor root/shoot ratio due to the scarce supply of photosynthate. Therefore, the relatively small root of corn under sole cropping could be less efficient in using resources (moisture and nutrients) as compared to the roots of intercropped corn, which might have better distribution and eventually better use of resources.

Effect of Intercropping Potato/Corn on Soil Moisture Storage (SMS) Evapotranspiration (ET) and Water Use Efficiency (WUE) VS Potato Yield

Intercropped potato with corn did not have any significant effect on SMS as compared to its sole crop (Table 3). However, the values of SMS were generally lower under intercropping than under sole cropping. This fact was not expected due to the lower values of both air and soil heat units (Table 1) and to lower values of ET obtained under intercropping as compared to sole cropping (Table 3). other factors such as water extraction of potato which might use 80% from its water requirement from soil depth of 20 -25cm (Sharaiha, unpublished data), while corn might have extracted water from the whole root zone, thus competition for water especially at the upper part of soil depth might exist, leading to a reduction in SMS under intercropped potato as compared to sole potato. These results agree with the findings of TRENBATH (1976) and contradict the findings of JEIMING AND MIDMORE (1988), obviously due to different experimental conditions, where they used plastic mulch in the first experiment and irrigation was not practiced in the second experiment. Moreover, the reduction in SMS did not affect the higher yields of potato obtained under intercropping (Table 3 and 1), as long as irrigation was applied. Furthermore, the ET values obtained for intercropped potato was generally lower than the values obtained by potato sole crop (Table 3). However, the lowest significant values of ET was obtained for intercropped potato was obtained under 1:2 potato/corn intercropping row arrangement as compared with potato sole croppping due to the effect of shading caused by corn plants. However, potato yield under this treatment was not significantly higher than potato yield under sole cropping. Similar results were obtained by AL-QAHWAJI (1995), in his work on potato faba bean intercropping. On the other hand, potato

yield was higher under intercropping than under sole cropping especially when potato was planted with corn in 2:2 row arrangement, where a significant difference was obtained under insignificant values of ET, this could be due to other factors that caused the higher yield production of potato, such as air and soil heat unit and light interception (Table 1), where they were higher under this treatment than the treatment of potato sole crop. RADKE AND HAGSTROM (1976) explained the higher yield production due to higher dry matter obtained by sheltered crops, where their transpiration to evaporation ratio is higher than unsheltered crops. Aside from the reduction of SMS and ET under potato/corn intercropping, WUE was improved significantly (Table 3). The higher significant values of WUE obtained by intercropped potato were due to higher yields of potato as compared to potato sole crop, since WUE was calculated by dividing yield over ET. The higher potato yields obtained under intercropping system, could be due to the interactions among different factors under 2:2 and 1:2 row arrangements

Effect of Intercropping Corn/Potato on Soil Moisture Storage (SMS) Evapotranspiration (ET) and Water Use Efficiency (WUE) VS Corn Yield

Table 4, shows that when corn was planted with potato, the values of SMS tended to be higher than the values obtained by corn grown as a sole crop. Similar results were obtained by OLASANTAN (1988) in his study on corn/watermelon intercropping, who suggested that watermelon protected the soil against insulation, helping water to infiltrate and minimize water losses by evaporation. However, corn water consumptive use (ET) was also increased when it was planted with potato as compared to corn sole cropping (Table 4), especially under 2:1 corn/ potato row arrangement where significant differences were obtained. The higher values of ET could be related to the higher values of air and soil heat unit, (Table 2) and SMS (Table 4) obtained under intercropped corn as compared to corn sole crop. These results contradicted the findings of AL-QAHWJI (1995), and agreed with the results obtained by JANA ET AL. (1995). Moreover, the values of WUE of intercropped corn were significantly higher than that of corn sole crop. The highest significant value of WUE for corn was obtained under 2:2 corn / potato intercropping row arrangement, where it gave an increase of 0.881 ton/ha/cm over the value of WUE obtained by corn sole crop. Therefore, the higher yield of intercropped corn as compared to the yield of corn sole crop could be related to the higher values of air heat unit, soil heat unit, light interception, SMS, ET and WUE (Tables 1 and 4) obtained under corn
Intercropping over corn sole cropping.

Efficiency of Intercropping

Land equivalent ratio (LER) is one of the methods used to evaluate the intercropping system, it is defined as the relative land area under sole cropping that is required to produce the yield achieved in the intercropping. When the values of LER are greater than one under intercropping, this result indicates greater efficiency or over yielding of land use compared to sole cropping. Table 5, shows that when corn and the two potato varieties (Fisia and Berca) were intercropped under 2:1 and 2:2 row arrangements, the LER values obtained were higher than one. It is also clear that the efficiency of intercropping was affected by the potato variety as well as by row arrangement. This is logical since each crop arrangement allowed for a special local microenvironment. Changing to a certain limit the competition for light, moisture and nutrients. Comparison of the relative LER values of corn intercropped with the two potato varieties (Fisia and Berca) under the two different row arrangement (Table 5), indicates that corn planted with potato "Frisia" was

more preferable than with potato "Berca". The highest relative LER was obtained when corn was planted with potato "Frisia" under 2:2 and 2:1 row arrangements, where corn gave 1.45 and 1.43, respectively. These values are 0.95 and 0.77 higher than the expected LER value obtained for corn sole crop in one half and two thirds of the land, where LER equal o.5 and o.66, respectively. Moreover, when corn was planted with potato "Berca" under the same row arrangements, the relative LER values obtained by corn were higher by 0.6 and 0.33, respectively as compared to corn sole crop planted in 0.5 and 3/3 of the land. The high efficiency of corn as it was planted with the two potato varieties found in this study agreed with the finding of WILLEY (1979), AL- QAHWAJI (1995), GLIESMAN, AND SHARAIHA AND HADIDI (2007) who explained this phenomenon from the complementary use of growth resources over time and space. Again, comparing the LER values of the two potato varieties (Fisia and Berca) intercropped with corn, it was observed that potato "Frisia" variety gave higher relative values of LER than potato "Berca" under the two intercropping row arrangements used (2:2 and 1:2), where potato "Frisia" gave a relative LER of 0.70 and 0.41, respectively. This could be attributed to the differences in yield between the two potato varieties grown under intercropping and sole cropping (Table 2-A). Moreover, the higher total LER of corn / potato intercropping was due to the higher contribution of corn, which might use the available resources better than corn planted under sole cropping.

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Table 1: Effect of Light Interception Air and Soil Heat Units on Yields of Two Potato Varieties under Intercropping with Corn and Sole Cropping.

Row arrangements	Light Interception $\mu mol.m^{-2}s^{-1}$	Average Air heat unit	Average Soil heat Unit	Yield Ton / ha
2 rows potato Fisia 2 rows corn	907 d	2014 c	1205 b	36.0 a
2 rows potato Berca 2 rows corn	1006 c	2203 b	1553 ab	34.1 a
1 rows potato Fisia 2 rows corn	807 e	1997 e	1134 b	31.4 ab
1 rows potato Berca 2 rows corn	842 de	2007 d	1185 ab	31.5 ab
Potato Frisia Sole crop	1257 b	2224 a	1285 a	25.7 b
Potato Berca Sole crop	1350 a	2231 a	1341 a	27.7 b

Values without common letters are significantly different using DMRT at 0.05 level

Air and soil heat units are analyzed separately – soil heat unit at 5cm depth.

Heat unit or daily growth is measured by using the 50-86°F

Table 2: Effect of Light Interception Air and Soil Heat Units on Yields of Corn under Intercropping with Two Potato Varieties (Frisia and Berca) and Sole Cropping.

Row arrangements	Light Interception $\mu mol.m^{-2}s^{-1}$	Average Air heat unit	Average Soil heat Unit	Yield Ton / ha
2 rows corn 2rows potato Frisa	1147 ab	2222 a	1671 a	3.33 a
2 rows corn 2rows potato Berca	1206 a	2220 a	1612 a	2.54 b
2 rows corn 1 row potato Frisa	1152 b	2216 a	1503 ab	2.47 b
2 rows corn 1 row potato Berca	1154 b	2198 b	1130 ab	1.66 c
Corn Sole crop	1112 c	2193 b	1019 b	1.15 c

Values without common letters are significantly different using DMRT at 0.05 level

Air and soil heat units are analyzed separately – soil heat unit at 5cm depth.

Heat unit or daily growth is measured by using the 50-86°F

Table 3: The effect of soil moisture storage (SMS) evapotranspiration (ET) and water use efficiency on the yields of two potato varieties under intercropping and sole cropping

Row arrangements	SMS mm	ET mm	WUE Ton/ha/cm
2 rows potato Fisia 2 rows corn	25.14 a	25.9 ab	1.314 a
1 row potato Frisia 2 rows corn	23.23 a	23.9 b	1.311 a
Potato Frisia Sole crop	27.6 a	28.5 a	0.903 a

Values without common letters are significantly different using DMRT at 0.05 level

Missing data for potato Berca was due to uncontrollable conditions

Table 4: The effect of soil moisture storage (SMS) evapotranspiration (ET) and water use efficiency on the yields corn under intercropping and sole cropping

Row arrangements	SMS mm	ET mm	WUE Ton/ha/cm
2 rows corn 2 rows potato Fisia	23.6 a	24.42 ab	1.37 a
2 rows corn 1 row potato Frisia	24.87 a	25.67 a	0.963 b
corn Sole crop	21.9 a	23.52 b	0.489 c

Values without common letters are significantly different using DMRT at 0.05 level

Missing data for potato Berca was due to uncontrollable conditions

Table 5: The relative yields, relative LER and total LER of the two potato varieties (Berca and Frisia) and bean grown under intercropping system

Row Arrangements	Relative yield Ton/ha		Relative LER		Total LER
	Potato	Corn	Potato	Corn	
2 rows potato Frisa 2 rows corn	18.0	1.66	0.70	1.45	2.15
2 rows potato Berca 2 rows corn	17.05	1.27	0.61	1.10	1.71
1 row potato Frisia 2 rows corn	10.46	1.65	0.41	1.43	1.84
1 rows potato Berca 2 rows corn	10.5	1.11	0.38	0.96	1.34

Each sole crop = one