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Adopting intercropping system for potatoes as practice on drought mitigation under Tunisian conditions

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Abstract. The adoption of intercropping systems in the irrigated perimeters can constitute an "agronomic way" to increase the added value by used m^3 of water. The objective of this research was to evaluate the efficacy of intercropping potatoes with green bean compared to monoculture potatoes. Intercropped potatoes showed no significant reduction in yield when compared to monoculture potatoes. Green beans yields were reduced when concurrently intercropped. The relative yield total (RYT), a measure of intercropping productivity, was 1.55 indicating that it would require 55% more land for separate monoculture plantings of potatoes and beans to produce a yield equivalent to the intercropping system. On the other hand, the intercropping system engendered an increase in the water and in the radiation use efficiencies (WUE_{MST} and RUE_{MST}) from 8.69 kg/m^3 to 10.15 kg/m^3 and from 4.47 g/MJ to 4.77 g/MJ, respectively. Finally, a linear relation between the accumulated absorbed radiation and the accumulated evapotranspiration was able to be revealed. Intercropping potatoes with green beans increases output per unit area and enables growers to take full advantage of the available natural resources.

Keywords. Intercropping – Potato – Green bean – Drought – Relative yield – Total water – Radiation use efficiencies.

Adoption d'un système de culture intercalaire de pommes de terre comme pratique pour atténuer la sécheresse sous les conditions de la Tunisie

Résumé. *L'adoption de systèmes de cultures intercalaires dans les périmètres irrigués peut constituer une "forme agronomique" d'augmenter la valeur ajoutée par m3 d'eau utilisée. L'objectif de cette étude était d'évaluer l'efficacité d'intercaler des pommes de terres avec des haricots verts, comparée aux pommes de terre en monoculture. Les pommes de terre intercalées n'ont montré aucune réduction significative de rendement par rapport aux pommes de terre en monoculture. Le rendement des haricots verts a été réduit lorsqu'il était concurrencé par la culture intercalée. Le rendement relatif total (RYT), une mesure de la productivité en culture intercalaire, était de 1,55, ce qui signifie qu'en monoculture séparée de pommes de terre et de haricots verts il faudrait 55% de terre en plus pour atteindre un rendement équivalent à celui du système intercalaire. D'autre part, le système intercalaire a entraîné une augmentation de l'efficacité d'utilisation de l'eau et du rayonnement (WUEMST et RUEMST) qui est passée respectivement de 8,69 kg m-3 à 10,15 kg m-3 et de 4,47 g MJ-1 à 4,77 g MJ-1. Finalement, une relation linéaire a pu être révélée entre le rayonnement absorbé accumulé et l'évapotranspiration accumulée. Les pommes de terre intercalées avec les haricots verts ont permis d'augmenter la production par unité de surface, et ainsi les cultivateurs ont pu valoriser pleinement les ressources naturelles disponibles.*

Mots-clés. *Culture intercalaire – Pomme de terre – Haricot vert – Sécheresse – Production relative – Eau totale – Efficacité de l'utilisation de l'eau et du rayonnement.*

I – Introduction

Studies of certain combination of crops showed an increase in water use efficiencies of each of these crops over monoculture without significant increase in water consumption. In this context, Oluwasemire *et al.* (2002) have reported that millet in monoculture presented a lower water use efficiency (2.49 kg/m^3) than the intercropping system millet-cowpea (2.89 kg/m^3). Similarly, Caviglia *et al.* (2004) reported mixed system wheat-soybean as more efficient in water use (3.12 kg/m^3) than soybean in monoculture (1.64 kg/m^3). Elsewhere, Natarajan and Willey (1980) and Keating and Carberry (1993) found that radiation intercepted by a mixed system is higher than that in monoculture for different combinations of corn-pigeonpea and sorghum-pigeonpea. Similar results were also reported by Marshall and Willey (1983) for the association millet-groundnut. Indeed, these authors established that the radiation use efficiencies of a mixed system (4.3 g/MJ) were greater than one in monoculture of millet (4.1 g/MJ). In Tunisia, potato is being grown widely with 24,300 ha distributed into 25,000 plots and practiced by 18,000 producers. About 78% of these farmers have a total surface lower than one hectare and 14% of less than two hectares. According to local climate there are three planting dates: August-September, December-January and February-March. More than 50% of the total potato surfaces were installed in February. During this growing season (February-May), irrigation needs constitute the first limiting factor of potato production due to the crop water requirements (400-500 mm) and the low precipitation which can only covers 15 to 20% of these needs. So the durability of this activity, mainly at the level of the small exploitations, goes by the improvement of the economic productivity of their cropping system. The adoption of intercropping systems in the irrigated perimeters can constitute an "agronomic way" to increase the added value by used m^3 of water. The objective of this research was to evaluate the efficacy of intercropping potatoes with green bean compared to monoculture potatoes. Comparisons will focus on evaluating yield, the relative yield total and water and radiation use efficiencies.

II – Materials and methods

1. Experimental plot

The experiment was conducted at the Technical Centre of Potato situated in the low valley of Medjerda river at Saida, Tunisia (lat. 37°, long. 10°, alt. 328 m). The soil of the experimental site was a clay-loam soil with a total available water of 180 mm/m. The salinity of water was about 2 g/l.

2. Plant material

The plant material is composed of one potatoes variety (Spunta) and one beans variety (Belna). The experimental design is adopted random block with three replications. Each elementary plot has 7 m length and 4.8 m width. Potatoes planting were conducted in 23 March 2005 with a density of 37,878 plants/ha. Beans planting has been performed manually (between 2 and 4 April) with a density of 220,000 plants/ha in monoculture and 120,000 plants/ha in intercropping system.

3. Experimentation

A. Crop growth and production

The observations were made on leaf area and total dry matter (g/m^2). To this end, seven samples were taken on the following days after potatoes planting: 53, 60, 67, 74, 81, 90 and 95 DAPP. At each sampling, three plants by plot (potato and/or beans) were collected. After separation of the plant organs, leaf area and fresh weight were measured. The weighings were made using a precision balance (Sartorius, Model PB3001). Leaf area measurements were made by a planimeter (Li-Cor, Model LI 3000A) and considering plant density, leaf area index (LAI) was determined. After drying at 65°C, the dry weights were measured until constant mass.

B. Soil water content

Throughout the cycle, soil water content was measured by the mean of a neutron probe (Brand Nardeux, Model Solo 25). To this end, nine tubes were installed, with three in each experimental unit (monoculture potatoes, monoculture beans and intercropped potatoes-beans). The measurements were carried every 10 cm until a soil depth of 100 cm. The neutron probe was calibrated from gravimetric measurements of water content.

C. Climate

Climate data were recorded daily by the mean of an automatic agrometeorological station. Collected data were daily solar radiation (R_s), minimum and maximum temperatures (T_{min} and T_{max}), minimum and maximum air relative humidities (HR_{min} and HR_{max}), wind speed (V) and rainfall (P). Reference evapotranspiration (ET_0) was estimated by the MABIA-ET_0 software using the FAO-Penman-Monteith approach.

4. Theoretical formulations

A. Estimation of absorbed photosynthetically active radiation

Photosynthetically active radiation (PAR) absorbed by vegetation was calculated using the formula of Beer (Manrique *et al.*, 1991):

$$PAR_{abs} = PAR_0\left(1 - e^{-k\,LAI}\right),$$

with: PAR_0: photosynthetically active radiation incident, which is equal to half the solar radiation ($MJ/m^2/j$); k: the light extinction coefficient by potatoes and / or bean which is equal respectively to 0.57 and 0.8; LAI: leaf area index.

B. Radiation and water use efficiencies

Radiation and water use efficiencies (RUE and WUE, respectively) were calculated from the total dry matter (TDM) as follows:

$$RUE\ (g/MJ) = TDM / PAR_{abs}$$

$$WUE\ (kg/m^3) = TDM / WC\ ,$$

with WC: total water consumption.

5. Statistical analysis

The results were subjected to variance analysis of one factor by general linear model (GLM). This analysis was performed using SPSS 10.0 software. The ensemble was completed by multiple comparisons of means with Student Newman Keuls test.

III – Results and discussion

1. Radiation use efficiencies

The results (Fig. 1) prove that the total dry matter increases linearly with the radiation absorbed PAR for potatoes and beans monocultures (before and after flowering) and also for the intercropping system potatoes-beans. Variance analysis showed that there was a highly significant effect (at 5%) of culture system on RUE. Moreover, the radiation use efficiency in intercropping beans system was significantly higher than in bean monoculture. Similarly, it was significantly higher in potatoes mixed crop than in potatoes alone. The radiation use efficiencies result in monoculture of potatoes (4.47 g/MJ) was relatively higher than that found by other authors as Fahem and Haverkort (1988) and Keating and Carberry (1993) who reported values between 1.8 and 3.7 g/MJ. On the other hand, radiation use efficiency in beans monoculture (before and after flowering) was more important than that obtained for potatoes monoculture which were 2.13 and 7.7 g/MJ, respectively. Concerning potatoes-bean intercropping system, the results showed that the radiation use efficiency was equal to 4.77 g/MJ. This enhancement in the RUE for the mixed system can be explained by the increase in the absorbed radiation PAR. These results confirm those obtained by Caviglia *et al.* (2004) for wheat-soybean and Rezig *et al.* (2007a) for potatoes-sulla in intercropping systems who founded that RUE in monocultures is lower than the one in mixed systems.

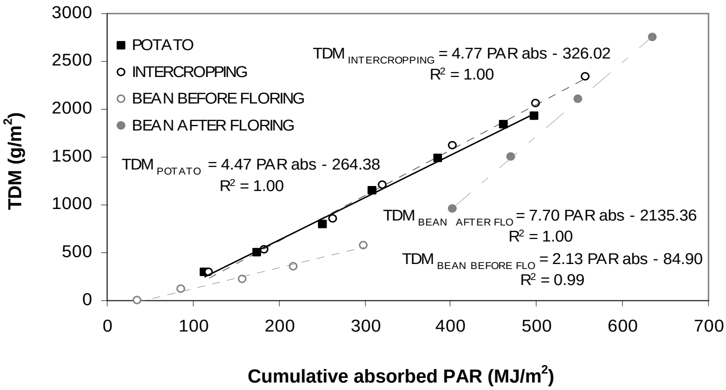

Fig. 1. Relationship between total dry matter and cumulative PAR absorbed.

2. Water use efficiencies

The results (Fig. 2) confirm that the total dry matter increases linearly with the water consumption for potatoes and beans monocultures. Variance analysis showed that there was a highly significant effect (at 5%) of culture system on WUE. The water use efficiencies obtained for the studied cropping systems were between 4.06 and 14.88 kg/m^3. These values were attained for beans monoculture system, before and after flowering, respectively. However, the water use efficiency result in monoculture of potatoes was unique for all the growing season and equal to 8.69 kg/m^3. Moreover, the water use efficiency in the potatoes-bean intercropping system was 13.5% greater than one in monoculture (10.15 kg/m^3). Similar results were found for wheat-soybean by Caviglia *et al.* (2004) and potatoes-sulla by Rezig *et al.* (2007a) in intercropping system.

3. Relationship between water consumption and radiation intercepted

A linear relationship was found between water consumption and actual cumulative absorbed PAR for the three cropping systems, monocultures and mixed potatoes and beans cropping systems (Fig. 3). For potatoes and beans monocultures, the cumulative water consumption increases linearly with absorbed PAR accumulated. The slopes of these curves were respectively equal to 0.51 10^{-3} and 0.46 10^{-3} m^3/MJ. Intercropping system potatoes-beans does not affects the linear correlation founded between water consumption and absorbed PAR (Fig. 3) and a slope of 0.46 10^{-3} m^3/MJ was obtained. This value was lower than the one obtained for potato monoculture. Indeed, the expansion of vegetation cover in the intercropping system increases the intercepted energy by the association and reduces water consumption by reducing soil evaporation. Similar relationships between water consumption and absorbed PAR accumulated were found for mono crop of potatoes (Sahli *et al.*, 2003; Rezig *et al.*, 2007b) and intercropping system sulla-potatoes (Rezig *et al.*, 2007a). These relationships reflect the interdependence between resources use by cultures when they are conducted in monoculture or in association.

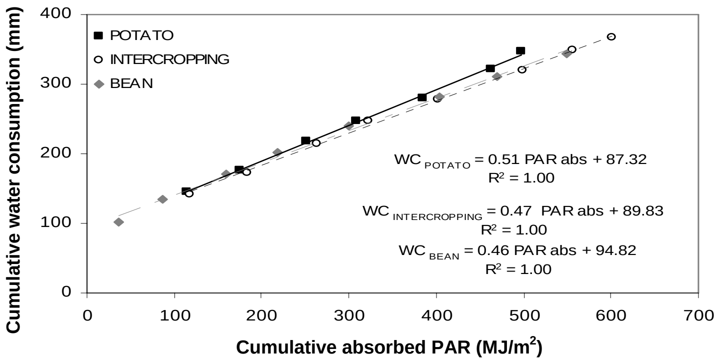

Fig. 2. Relationship between total dry matter and cumulative water consumption.

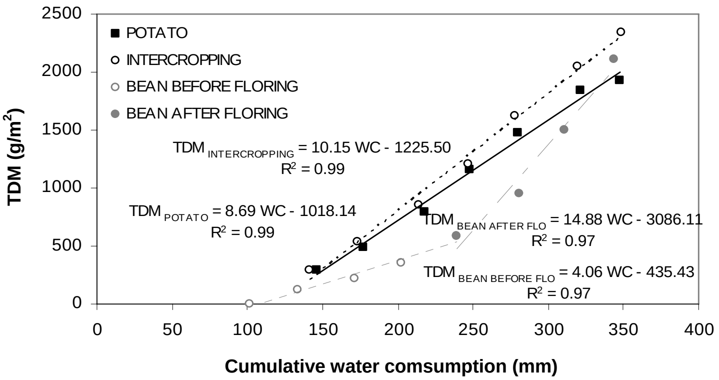

Fig. 3. Relationship between cumulative water consumption and cumulative PAR absorbed.

IV – Conclusion

This work studied the agronomic performance of intercropping system potatoes green beans in terms of water and radiation use efficiencies depending on the available water resources. The total dry matter production may be linked to plant water consumption following a simple linear relationship. Similarly, dry matter accumulation seems to be closely related to the radiation intercepted amount by the crop under a simple linear relationship. The intercropping system seems to improve the water and radiation use efficiencies compared to the monoculture of potatoes. Finally, a linear relation was found between the absorbed PAR radiation and the actual evapotranspiration. The slope of this line regression is 0.51 for the potatoes alone and is 0.46 10^{-3} m^3/MJ of PAR for intercropping potatoes-bean.

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