INTERACTIONS OF Capsicum annuum L IN MONOCULTURE AND IN INTERCROPPING WITH Setaria verticillata (L.) P. BEAUVOIS.

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ABSTRACT

Mixture is a system of two or more different plant species interacting with each other in different manners. Interspecific competition, resource complementarity and facilitation may modulate better performance of a mixture. It is difficult to interpret the results of a simple mixture experiment, if the phenomena act together. An experimental design is used to study interactions between chilies or peppers, Capsicum annuum L. var. 'Baklouti' and Setaria verticillata (L.) P. BEAUVOIS. A replacement series design was used to compare C. annuum/ S.verticillata interactions under monocultures vs. polycultures. The experiment is conducted in the greenhouse of the Higher Institute of Agricultural Sciences, of Chott-Mariem, 4041, University of Sousse, Institution of Agricultural Research and Higher Education (IRESA), Ministry of Agriculture and Water Resources, Tunisia during 2011-2012 crop season. In this replacement experiment, C. annuum and S. verticillata seedlings were transplanted into pots with different proportions of both species (0/6, 1/5, 2/4, 3/3, 4/2, 5/1, 6/0). Dry weights of two species were measured at the harvest time at 40 days age from transplantation. The relative interaction index, relative competition intensity and actual dry weight loss was calculated for both species. These intercropping evaluation indices showed that C. annuum is a weak competitor and S. verticillata is a strong competitor. The dry weight advantage was caused by the rapid growth of S. verticillata. C. annuum cannot grow with S. verticillata due to very competitive nature of this weed. The suppression of the later weed is unavoidable for growth of C. annum. Further studies are suggested confirm the present findings.

Keywords: Additive series, actual dry weight loss, chilies, peppers, relative interaction index, relative competition intensity.

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INTRODUCTION

Plants compete for light, water and soil nutrients and decrease the availability of these resources to other plants (Ghanizadeh et al., 2014). Weeds are considered stronger competitors than many crops because of their life-history, biological traits and production of allelochemicals (Dunbabin, 2007; Efthimiadou et al., 2009; Khan et al., 2016). The competitive relationship between plants is not only determined by these biological traits of the species but it is also affected by the environmental conditions (light, water, nutrient availabilities and disturbances) (Tilman, 1981; Efthimiadou et al., 2009), the duration of competition (Dunbabin, 2007; Stagnari and Pisante, 2011), plant density and spatial planting pattern (Aspasia et al., 2009; Marín and Weiner, 2014).

Chilies or pepperss, Capsicum annuum L. belongs to the family of Solanaceae (Kabura et al., 2008). It is a highly-value long season crop grown in most parts of the world, growing well in warm climates (Granberry and Colditz, 1990), an important vegetable crop all over the world (Peet, 2006) and ranks third in world’s vegetables exceeded only by tomatoes and onions (Akinfasoye et al., 2006). C.annuum is one of the most popular and highly remunerative annual herbaceous vegetable crops. C.annuum is an important horticultural vegetable grown in Tunisia owing to the considerable earnings and employment generated. C. annuum is prone to flushes of both winter and summer weeds during the course of its long growing cycle (Richard and LeStrange, 2007).

The yield of C. annum in Tunisia averages 12.5 t ha^{-1}, which is relatively low as compared to the yield realized in other Mediterranean countries such as Spain (35 t ha^{-1}), Italy (28 t ha^{-1}), Greece (23 t ha^{-1}) and Morocco (14 t ha^{-1}) [Boughalleb and El Mahjoub, 2005]. This low yield obtained in Tunisia is probably due to the impact of weed infestations, which is one of the limiting factors in C. annuum production (Adigun, 1984; Boatwright and McKissick, 2003).

When weeds are not controlled, they compete vigorously with C.annuum and can reduce yields 70 to 99% (Frank et al., 1992; Eschel et al., 1973). In previous studies, Hachem (2003) determined that the main weeds infesting C.annuum in Tunisia are rough bristle-grass Setaria verticillata (L.) P. Beauv., Chenopodium murale and Amaranthus lividus and few other species of lesser importance. S. verticillata is a cosmopolitan herbaceous grass weed of Poaceae family. It is native to Europe, but it is known on most continents as an introduced species and often a noxious weed. This is a loosely tufted annual grass with decumbent or erect stems growing from 300–1 000 mm high and with a C4 physiology. The combination of ready dispersal by its ‘sticky’ seed, its C_4 physiology and rapid growth make it an extremely successful invader (PIER, 2008). It occurs under irrigated conditions (Lee and Cavers, 1981).

In general, the damage of S. verticillata is moderately detrimental to crops. However, we must fear the early emergence of this weed that is able to reduce yields. As well as competing with a very wide range of tropical and temperate crops, it can cause difficulties during harvesting when the inflorescences become entangled with themselves and with the crop. It has inflicted considerable environmental and economic costs, and displacement of native grasses (Holm et al., 1977; Dekker, 2003; Abdullahi, 2004; Gözcü and Uludag, 2005; Kostov and Pacaoski, 2006). Yield losses caused by Setaria spp. are poorly documented. Yield reductions vary according to the date of emergence of Setaria spp relative to that of the crop. Yield reductions of 40% in beets and 75% in peas and beans have been measured in some trials (Douglas et al., 1985; Weill, 2007). One foxtail plant m^{-2} reduced Panicum virgatum L. yield in the first production year by 25%, and yield loss was 90% or greater at densities > 50 foxtail plants m^{-2} (Larson et al., 2016). A giant foxtail (Setaria faberii Herrm.) infestation of one plant per ft in 30-inch rows reduced yield by 13% (Nave and Wax, 1971).

Moreover, S. verticillata can act as an alternative host for the nematodes and viruses of many crops (Holm et al., 1977; Ibrahim et al., 2000). S.verticillata has a potential source of useful drugs due to the presence phytochemicals and can be utilized in the treatment of many diseases and also be oppressed for use in the pharmaceutical and cosmetic industries (Shivakoti et al., 2015).

Weed competition studies in some horticultural crops are well documented (Zimdahl, 2004), Weed competition studies in horticultural crops such as Lycopersicum esculentum are well documented (Friesen, 1979; Labrada and Santos, 1977; Singh, Bhan and Tripathi, 1984;) but, it is imperative to note that; very limited information is available about the competitive ability of C. annum towards S. verticillata (Frank et al., 1988).

Therefore, the overall objective of the study was to investigate the effects of interactions between C.annuum under monoculture and intercropping conditions with or without the presence of S.verticillata. More precisely, the three main objectives were as follows: 1) to investigate whether the growth of C.annuum and S.verticillata differs between monocultures (intra-specific interaction) and intercropping (inter-specific interaction) 2) to examine the growth of S. verticillata under C. annuum and S. verticillata in monoculture and intercropping.

MATERIALS AND METHODS

Two common experimental designs that have been used to compare C. annuum/ S. verticillata interactions under monocultures vs. polycultures in the greenhouse are the replacement series and the additive series design. In additive series design, C. annuum and S. verticillata are grown together. The density of C. annuum is kept constant, while the density of S. verticillata is varied. S. verticillata acts as a comparative indicator for the aggressiveness and competitiveness of C.annuum (Radosevich et al., 2007). While, in the additive experiment, C.annuum is planted at a fixed density of one plant/pot while S.verticillata is sown at 1, 2, 3 or 4 plants in the same pot.

In replacement series design, the main characteristic is to vary the proportions of both species while maintaining the overall density of the two species constant. Pot experiments were set up with the following treatments:

1) 100% C.annuum (6 plants/pot);
2) 83.3% C.annuum (5 plants/pot);
3) 66.6% C. annuum (4 plants/pot);
4) 50% C.annuum (3 plants/pot);
5) 33.3% C.annuum (2 plants/pot);
6) 16.6% C.annuum (5 plants/pot);
7) 0% C.annuum.

This design is suitable to investigate yield advantage of mixtures and to investigate to what degree resource partitioning might contribute to a yield advantage (Sobkowicz and Podgórska-Lesiak, 2007).

The two experiments were conducted in greenhouse in Fall, 2011 and 2012 (i.e., a two-year study) at Higher Institute of Agricultural Sciences of Chott-Mariem (Sousse,Tunisia). The experimental units were plastic containers (8 cm in diameter and 10 cm deep) filled with a standard horticultural potting medium (sand, manure, perlite; 1:1:1, v/v). Based on previous observations, this container size was chosen to provide unrestricted C. annuum and S. verticillata growth for 40 days. C.annuum var. 'Baklouti' was sown in container filled with peat moss and at the true two-leaf stage seedlings were transplanted into each pot following each experimental design. S. verticillata seeds were collected from local field stands of populations growing in C.annuum fields near Higher Institute of Agricultural Sciences of Chott-Mariem. These seeds were sown in each pot and seedlings that emerged were thinned to the desired densities and were allowed to interfere naturally with C.annuum for the reminder of the C. annuum season, i.e., 40 days.

At the end of the experiment (after 40 days), all plants were harvested, dried at 80°C for 48 h, and then weighed. Using mean dry weight data, we calculated the relative competitive intensity (RCI) and the relative interaction index (RII) and actual dry weight loss (ADWL). Direct effects were calculated by using Relative Interaction Intensity indices (RII; Armas et al., 2004) to make comparisons of competitive performance. RII is a measure of the strength of interaction between species centered on zero with negative interactions (competition) indicated by values between 0 and -1, and positive interactions (facilitation) indicated by values between 0 and +1. RII allows for simple comparisons of interaction strength across treatments.

1. The Relative Interaction Index

The Relative Interaction Index of C.annuum (RII) (Armas et al., 2004) was also used to quantify the interactions between the two species. In this study the relative intensity of the C.annuum interaction was assessed by calculating the relative interaction using the following formula :

$$RIIcap = \frac{(DWdwcapmix - DW_{dwcapmono})}{(DW_{dwcapmix} + DW_{dwcapmono})}$$

Where DWdwcapmix and DWdwcapmono are the dry weight of C.annuum in mixture with S.verticillata and that of C.annuum in monoculture, respectively.

And relative intensity of S.verticillata interaction was assessed by calculating the relative interaction using this formula:

$$RIIset = \frac{(DW_{dwsetmix} - DW_{dwsetmono})}{(DW_{dwsetmix} + DW_{dwsetmono})}$$

Where $DW_{dwsetmix}$ and $DW_{dwsetmono}$ are the dry weight of S.verticillata in mixture with C. annuum and that of S.verticillata in monoculture, respectively where the absolute value of the denominator is always greater than the absolute value of the numerator and hence has a finite range. This index represents the ratio of the net mass loss or gain due to the interaction (numerator) relative to the mass affected by only facilitative interaction and only competitive interactions (denominator), simultaneously. RII has values ranging from -1 to 1, is symmetrical around zero. If RII is 0, it indicates neutral interactions, while values < 0 indicate competition and values > 0 indicate facilitation (Armas et al., 2004).

Given a 95% confidence interval, a treatment was considered competitive if the RII value was less than −0.10, facilitative if the RII value was greater than 0.10, and neutral if the RII value was between −0.10 and 0.10 (Armas et al., 2004).

When pots with and without inter-specific interaction were compared, the target plant cannot grow without another neighboring species, the RII is +1; if the target plant cannot grow with another neighboring species, the RII is +1 (Craine, 2009)

2. Relative competition intensity

We used the relative competitive index (RCI) (Gan et al., 2009) to measure the interspecific interactions of C. annum and S.verticillata. The relative competitive index, which measures the proportional decrease in plant performance due to competition (Grace, 1995; Goldberg et al., 1999). The relative competition intensity (RCI) was calculated separately for each species in the intercropping system according to Grace (1995):

$$RCI_{cap} = \frac{(DW_{capmono} - DW_{capmix})}{DW_{capmono}}$$

Where DWdwcapmix and DWdwcapmono are the dry weight of C.annuum in mixture with S.verticillata and that of C.annuum in monoculture respectively.

$$RCI_{set} = \frac{(DW_{setmono} - DW_{setpmix})}{DW_{setmono}}$$

Where $DW_{dwsetmix}$ and $DW_{dwsetmono}$ are the dry weight of S.verticillata in mixture with C.annuum and that of S.verticillata in monoculture respectively.

Where, RCI is the coefficient of relative competition intensity, $DW_{capnosv}$ is the performance of the C. annuum in the absence of S.verticillata and DW_{capsv} is the performance of the C.annuum in the presence of S.verticillata (Silliman and Bertness, 2004). The values of RCI have no lower limit [no minimum (negative) value but has a maximum value of 1 indicating maximal competition (ranging from -∞ ≤ RCI ≤ +1)] and no symmetrical around zero. If RCI = 0, there is no competition between C.annuum and S.verticillata indicating neutral interactions. If RCI < 0, the performance of the C.annuum is better with the presence of S.verticillata than without S.verticillata. If RCI > 0, S.verticillata has a negative effect on C.annuum (Montserrat et al., 2004). In another terms, the species which has higher RCI values suggesting weaker competitors. If the values of RCI are ≥-∞, it indicates facilitation (Armas et al., 2004).

If RCI of C. annuum = 0, there is no effect of a S. verticillata. If RCI of C.annuum is positive, species C.annuum has less biomass in that treatment than S.verticillata and therefore competition is indicated. If the measure is negative, C.annuum has more biomass in the mixture and therefore there is no competition with species S.verticillata. Moreover, this number is the proportion of decrease (if positive) or increase (if negative) of C. annuum in mixture with respect to monoculture.

3. Actual Dry weight loss

Actual dry weight loss (ADWL) index, which gives more accurate information about the competition than the other indices between components of the mixture. The ADWL is the proportionate dry weight loss or gain of each species grown as intercrops compared to pure stand. The positive or negative values of ADWL indicate the advantage or disadvantage of the intercropping, i.e. it provides a quantitative assessment of the advantage/disadvantage accumulated in any system of intercropping when the primary purpose is to compare yield on a per-plant basis (Dhima et al., 2007; Yilmaz et al., 2008). The magnitudes of the individual AYLs of the component crops in an intercropped system reflect the nature of the competition between and within the crops. The ADWL was calculated as (Banik et al., 1996):

$$ADWL = ADWL_{Cap} + ADWLset$$

Where

$$ADWL_{Cap} = \{(DWcapmix/part\ of\ Cap\ in\ mix) / (DWcapmono\ /part\ of\ Cap\ in\ mono)\} - 1,$$

$$ADWLset = \{(DWsetmix/\ part\ of\ Set\ in\ mix) / (DWsetmono/\ part\ of\ Set\ in\ mono)\} - 1$$

The data collected were analyzed statistically using Fisher's analysis of variance technique and treatment means were separated using the least significant difference (LSD) at 0.05 probability level (Steel et al., 1997), using Fisher's protected LSD at P = 0.05 level.

RESULTS AND DISCUSSION

Competitive interactions among plants of the same or different species can have either a positive or a negative effect on growth (Mariotti et al., 2009; Tilman, 1988). In this study, we hypothesized that the dry weight for C. annuum and S. verticillata intercrops would be greater than that of the monocultures. Indeed, for C.annuum, it was found that the dry weight in intercrops with S.verticillata was generally lower than in monoculture.

However, it was also found that dry weight of S. verticillata in all cases of intercrop with C. annuum was greater than the dry weight of monocultures. It is known that C. annuum plants are usually not very competitive against weeds because of its slow growing habit (Qasem, 2006). This unbalanced benefit of both crops in intercropping has been previously observed, showing the complexity of the system and its interactions (Lithourgidis et al., 2011). Similar results were observed in a Allium porrum / Apium graveolens inter-crop mixture where total yield was equal to the yield in the two species in monoculture, but Allium porrum competition reduced Apium graveolens yield (Baumann, 2002). In a Lactuca sativa / Raphanus sativus intercrop, yield of Raphanus sativus was significantly less in intercrop compared to monoculture (Guvenc and Yildirim, 2006). This is known as asymmetric interspecific facilitation where the intercrop combination increases the yield of one species, but causes a decrease in the other (Li et al., 2006; Khan et al., 2015).

1. Relative Competitive Indices

Relative competitive indices (RCI) was calculated to make comparisons of competitive performance of each species in the mixture. The RCI of both species are shown in Table-1. The RCIs were positive for C.annuum and negative for S.verticillata in all intercropping combinations (Table-1), meaning that C.annuum faced more competition in the mixture than in pure stands and S.verticillata faced less competition in the mixture than in pure stands. These values of RCIs indicate that the performance of S. verticillata is better than C. annuum and S. verticillata has a negative effect on C. annuum. The sum of RCI_{cap} and $RCI_{set,}$ (RCI_{cap} + RCI_{set}), for both species in a mixture tended to be positive (Table-1), suggesting that intra-specific competition was more than inter-specific competition. Moreover the RCI varied with the treatment depending on the proportion of each species in the mixture. Montserrat et al (2004) had calculated the relative competitive indices (RCI) for alien weeds with crops. They found that the RCI varied with weed species and crop species; that is 0.19 for Brassica tournefortii and 0.69 for Solanum nigrum as weeds and 0.78 for Beta vulgaris and 0.13 for Saccharum officinale as crops, respectively.

The relative competition intensity values of S.verticillata (i.e., RCI) were less than zero, while greater than zero for C.annuum (i.e., RCI), indicating that the effects of intraspecific competition with C.annuum were stronger for S.verticillata and the opposite for C.annuum. Xu et al. (2013) had shown the same tendency for Bothriochloa ischaemum and Lespedeza davurica in intercropping system. The relative competition intensity values of Bothriochloa ischaemum (i.e., RCI) were less than zero, while greater than zero for Lespedeza davurica (i.e., RCI), indicating that the effects of intraspecific competition with Lespedeza davurica were stronger for Bothriochloa ischaemum, and the opposite for Lespedeza davurica.

2. Relative Interaction Index

Relative interaction intensity indices (RII) were calculated to make comparisons of competitive performance of each species in the mixture (Table-2). In this study, the RII_{cap} values of C. annuum grown in the presence of S. verticillata were negative (-1 to 0) in all intercropping system ratios (Table-2), indicating that S. verticillata competed well with C. annuum and the magnitude of the negative effect of S.verticillata on C. annuum was increased with the decrease of the proportion of S.verticillata (Table-2) from 1 to 0.55.

In contrast, The RII_{set} values of S.verticillata grown in the presence of C. annuum were positive in all intercropping system ratios, indicating that C.annuum did not compete very well with S.verticillata and the magnitude of the positive effect of C.annuum on S.verticillata increased as the proportion of S.verticillata decreased from 0.48 to 1. This result indicated that C.annuum could promote the growth of S.verticillata relative to growth in conditions of intraspecific interaction and the reverse for S.verticillata, it decreases the growth of C.annuum. That is, S.verticillata was a stronger competitor than C.annuum.

S. verticillata plants have experienced a (positive) facilitative effect from C.annuum plants since $RII_{set} > 0$ and C.annuum plants have experienced a (negative) competitive effect from S.verticillata since $RII_{cap} < 0$. Moreover The RII_{set} or RII_{cap} changed with the treatment from 0.10 to +0.48 for S. verticillata and from -0.22 to -0.55 for Capsicum as the density of each species in the mixture increases respectively indicating that all treatments are competitive and the competitiveness increases with the decrease of the proportion of each species. A greater absolute value of RII indicates a greater intensity of plant interaction (Gao et al., 2014). S. verticillata showed higher competitive abilities than C.annuum. The relative intensity of S.verticillata interaction with C.annuum increased with its density for all measures of performance in the intercropping interaction systems. In these treatments S.verticillata performed better in the presence of C.annuum than in its absence.

In similar study Armas and Pugnaire (2011) showed that some species were competitive, showing high competitive abilities towards other species, others showed neutral effects, and others showed facilitative effects and that suffered competition or were facilitated by other species. Armas and Pugnaire (2011) indicated that Quercus coccifera had a negative effect on both Q. suber and Olea europea ($RII_{Quercus\ coccifera} < RII_{Quercus\ suber}$ or $RII_{Olea\ europra}$), Q. coccifera showed high competitive abilities towards Q. suber and O.europra. Stipa tenacissima was a stronger competitor than Anthyllis cytisoides ($RII_{stipa\ tenacissima} = -0.38 \pm 0.04$ of Stipa on Anthyllis and $RII_{Anthyllis\ cytisoides} = +0.02 \pm 0.04$ of Anthyllis on Stipa). Both Anthyllis cytisoides and Stipa tenacissima had neutral effects on Retama sphaerocarpa($RII_{Anthyllis\ cytisoides} = 0$). Retama sphaerocarpa, however, had a positive effect on both Stipa tenacissima and Anthyllis cytisoides. These later were facilitated by Retama sphaerocarpa.

Li et al. (2015) showed that the RII of Ipomoea cairica (Ic) grown in the presence of Pueraria lobata (Pl) or Paederia scandens (Ps) was negative ($RII_{Ic(Pl)} = -0.280$, $RII_{Ic(Ps)} = -0.013$, respectively), indicating that Pueraria lobata or Paederia scandens competed well with Ipomoea cairica, and the magnitude of the negative effect of Pueraria lobata on Ipomoea cairica was larger than that of Paederia scandens on Ipomoea cairica (0.280 > 0.013). Pueraria lobata was a stronger competitor than Paederia scandens against Ipomoea cairica. In the same study, Li et al. (2015) indicated that the effect of Paederia scandens on Pueraria lobata was positive ($RII_{Pl(Ps)} = 0.112$) indicating that Paederia scandens could promote the growth of Pueraria lobata relative to growth in conditions of intraspecific interaction.

De-Haan and Vasseur (2014) studied the above and below ground interactions in monoculture and intercropping of Allium cepa and Lactuca sativa in greenhouse conditions. They found that the effect of Lactuca on Allium was competitive in the below ground and full competition treatments, but was neutral in the above ground competition treatment. Allium monoculture was facilitative in above ground interaction as well as below ground interaction, but when paired in full competition; the effects were slightly competitive. When Lactuca was paired with Allium above ground, there was a neutral effect, while a facilitative effect was observed when Lactuca was paired with Allium in below ground and full interaction treatments. The effects of Lactuca in intraspecific interaction above ground and below ground were competitive, while there was a neutral effect for Lactuca paired with Lactuca in full interaction. Also, Yi (2015) showed that the RII value of Allium cepa intercropped with Phaseolus vulgaris was 0.35 and the RII value of Phaseolus vulgaris intercropped with Allium cepa was -0.21. This showed that a mild facilitative effect on Allium cepa would be found with the presence of Phaseolus vulgaris, suggesting a mild competitive effect against Phaseolus vulgaris in the presence of Allium cepa (Armas et al., 2004).

3.Actual Dry Weight Yield Loss (ADWYL) of C. annuum and S. verticillata in replacement series design.

The ADWL values for C. annuum were negative for the combinations like C5S1 and C4S2, and positive for the combinations like C3S3, C2S4, and C1S5. They ranged from -0.38 to +0.80, the highest was obtained from C1S5 and the lowest was from C5S1 indicating an actual yield loss of 38.0 to 80 % compared to sole C. annuum DW (Table-3). Setaria DWL had positive in all Setaria-Capsicum intercropping system ratios. They ranged from +17.17 to +0.48; the highest $ADWL_{set}$ value was obtained from C5S1. While the lowest was from C1S5 (Table-3) indicating a dry weight yield gain of 48 to 1717%, compared to sole S.verticillata DW (Table-3). The replacement of Capsicum by Setaria in the mixture, in other terms, the increase of the Setaria proportion in the mixture decreased the

Setaria ADWL from 1717 to 48%, and increased the Capsicum ADWL from -38% to + 80% (Table-3).

AYLsv had positive values in all intercropping patterns Setaria – C. annuum (Table-3), which indicates a DW advantage for S.verticillata, probably because of the positive effect of C. annuum on S.verticillata, when grown in association.

It was also revealed that in S.verticillata–C. annuum intercropping patterns, S.verticillata was the dominant one because the partial AYL of S.verticillata was greater than the partial AYL of C. annuum. According to Banik et al. (2000), the AYL index can give more precise information than the other indices on the inter- and intra-specific competition of the component species and the behavior of each species involved in the intercropping systems. Quantification of yield loss or gain due to association with other species or the variation of the plant population could not be obtained through partial RYs, whereas partial AYL shows the DWL or DWG by its sign and as well as its value. Thus, there was an increase by 1717% (AYL_{SV}= +17.17) and by 48% (AYL_{sv} = +0.48) in DW of S.verticillata in the intercropping patterns at C5S1 and C1S5, respectively, as compared to its sole culture (Table-3).

In contrast C.annuum presented ADWL positive at C2S4 and C1S5 . at C1S5 the ADWL of C.annuum was greater than the ADWL of S.verticillata. This indicates that at high proportion of S.verticillata the effect of S.verticillata on C.annuum was reduced,

The increase of the actual dry weight loss of C. annuum ($ADWL_{Cap}$) from -0.38 to +0.48 was associated with de decrease of its proportion in the mixture. The decrease of the actual yield loss of S. verticillata ($ADWL_{Set}$) from +17,17 to +0.48 was associated with the increase of its proportion in the mixture. The decrease of the total actual yield loss ($ADWL_{total}$) from +16.79 +1.28 was associated with the increase of C. annuum and the decrease of S. verticillata respectively.

This decrease was approximately +15.51 %. Moreover, the increase or the decrease of ADWL was not proportional to the increase of the proportion of S.verticillata or the decrease of the proportion of C. annuum in the mixture. These results indicate an intraspecific interaction that might be between species and this intraspecific interaction is stronger than the interspecific interaction. Also, S. verticillata showed a strong competition.

Likewise, Takim (2012) found that the AYL values for Vigna unguiculata intercropped with Zea mays were all negative and ranges from -0.257 to -0.813 indicating a yield loss of 25.7% to 81.3%, compared to sole Vigna unguiculata yield under the southern Guinea savanna conditions in Nigeria. However, under the East Mediterranean conditions in Turkey, Yilmaz et al (2008) reported that the AYL values for V. unguiculata intercropped with Zea mays were all negative and ranged from -0.02 to -0.42 indicating a yield loss of 2 to 42% compared to sole V. unguiculata yield. Aynehband and Behrooz (2011) indicated that the Zea mays AYL had positive values in the Zea mays/ Amaranthus cruentus intercropping system ratios (25% to 75%). AYLvetch had positive values in the common vetch–wheat (55:45) mixture and in the common vetch–triticale (65:35) mixture, which indicates a yield advantage for common vetch (Dhima et al., 2007). Likewise, Mondal et al. (2018) inferred from their studies that cauliflower intercropped with balsam is the best treatment and recommended the marginal farmers for realizing more profit.

CONCLUSIONS

The results of a replacement-series competition study clarified the interaction between C. annuum and S. verticillata that have opposite effects. The competitive relation between C. annuum and S. verticillata changed with the proportion of each species in the mixture. S.verticillata performed better in the presence of C.annuum than in its absence. S. verticillata plants have experienced a (positive) facilitative effect from C. annuum plants. These intercropping evaluation indices showed both S. verticillata and C. annuum faced less competition in the mixture than in their pure stands. Intra-specific and inter-specific competition co-occurs in C. annuum and S. verticillata. Intra-specific competition was more than inter-specific competition between these two plant species. However, a single factor, such as proportion, is not enough to predict interference between these two species. Future studies should evaluate the effect of water, light and nutrients on the co-growth of these species.

Table-1. Relative Competitive Indices of C. annuum and S. verticillata in replacement series study.

Treatments	RCIcap	RCIset	RCIcap + RCIset
C6S0(capmono)	1	*	1
C5S1(mix)	0,43 ±0.02	0,20 ±0.02	0.63
C4S2(mix)	0,37 ±0.01	-0,03 ±0.01	0.34
C3S3(mix)	0,53 ±0.03	-0,51 ±0.03	0.02
C2S4(mix)	0,63 ±0.04	-0,06 ±0.01	0.59
C1S5(mix)	0,48 ±0.03	-0,29 ±0.02	0.19
C0S6(setmono)	*	1	1

Means ± SE in each column followed by same letters at superscripts are not significantly different at p = 0.05 based on LSD test. Experiment was repeated twice.

Table-2. Relative interaction index of C.annuum and S.verticillata in replacement series design.

Treatments	RIIcap	RIIset
C6S0(capmono)	-1	0
C5S1(mix)	-0.22	+0.48
C4S2(mix)	-0.27	+0.34
C3S3(mix)	-0.36	+0.18
C2S4(mix)	-0.45	+0.11
C1S5(mix)	-0.55	+0.10
C0S6(setmono)	0	+1

Means ± SE in each column followed by same letters at superscripts are not significantly different at p = 0.05 based on LSD test. Experiment was repeated twice.

Table-3. Actual Dry weight loss (ADWL) of C.annuum and S.verticillata in replacement series study.

Treatments	ADW loss		
	$ADWL_{Cap}$	$ADWL_{Set}$	$ADWL_{Total}$
C6S0	*	*	*
C5S1	-0.38 ±0.02	+17.17 ±1.25	+16.79
C4S2	-0.15 ±0.01	+5.30 ±0.58	+5.15
C3S3	-0.06 ±0.01	+1.90 ±0.23	+1.84
C2S4	+ 0.14 ±0.01	+0.91 ±0.10	+1.05
C1S5	+0.80 ±0.03	+0.48 ±0.05	+1.28
C0S6	*	*	*

Means ± SE in each column followed by same letters at superscripts are not significantly different at p = 0.05 based on LSD test. Experiment was repeated twice.

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