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Original Article

The Effect of Intercropping and Nitroxin Biofertilizer on Yield Components and Relative Yield Total of Purslane (*Portulaca oleracea* L.) and Dragon's Head (*Lallemantia iberica* Fisch. & C.A. Mey)

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Abstract

A field study was conducted in order to evaluate the effects of intercropping and biofertilizers on yield and yield components of purslane (*Portulaca oleracea* L.) and dragon's head (*Lallemantia iberica* Fisch. and C.A. Mey). The experiment was factorial on the basis of a randomized complete block design with three replications. The first factor was an additive intercropping system including monocultured purslane, monocultured dragon's head, intercropping of 100% purslane + 25% dragon's head, intercropping of 100% purslane + 50% dragon's head, intercropping of 100% purslane + 75% dragon's head; the second factor was nutrient treatments including application of 50% inorganic N fertilizer (urea) + nitroxin, inorganic N fertilizer (urea), nitroxin and no fertilizer. Results showed that as the density of dragon's head increased, the number of branches in purslane decreased. In purslane, the number of capsules was significantly affected by intercropping and application of biofertilizers. In both crops, the effects of treatments on yield were significant. Results clearly showed that Relative Yield Total (RYT) was always higher in intercropping than monocultured systems. The highest RYT was observed in intercropping of 100% purslane + 50% dragon's head with the application of 50% inorganic N fertilizer (urea) + nitroxin. Therefore, combination usage of biofertilizers and inorganic N fertilizers can improve yields in purslane/dragon's head intercropping.

Keywords: monoculture, number of branches, relative yield total, seed weight, yield

Introduction

The environmental challenges attributed to agriculture are related primarily to reduce soil, water and air quality, often arising from inappropriate nutrient management strategies. Farmers typically use chemically intensive practices to maintain soil productivity combined with other management practices that decrease soil organic matter (SOM), while increasing soil erosion, acidification and salinization (Dumanski *et al.*, 1986). Intercropping, which is defined as growing two or more species simultaneously in the same field during a growing season, is considered one important strategy in developing sustainable production systems, particularly systems that aim to limit external inputs (Adesogan *et al.*, 2002; Jahansooz *et al.*, 2007; Zhang *et al.*, 2008). The range of benefits identified from intercropping two or more species include higher productivity and profitability per unit area, improved soil fertility through nitrogen fixation, increased efficiency of resources, reduced damage caused by pests, diseases and weeds, improved forage quality and improvements in carbon and nitrogen dynamics (Oelbermann and Echarte, 2011).

To reduce pollution, restoration of land and wetlands, and excessive use of our non-renewable resources such as petroleum, which are used in the chemical fertilizers production, alternative methods must be developed. For this reason, environmental friendly product such as biofertilizer should be used when realizing agro-ecological restoration and sustainable ecosystem, which are the component of ecological engineering. Mitsch (1998) defined the ecological engineering as "the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both". Therefore, using biofertilizer and selection of the best microorganism strains have vital role when integrating human society with vulnerable ecosystems. Biofertilizers are products containing living cells of different types of microorganisms, which have an ability to convert nutrionally important elements (N, P, etc.) from unavailable to available forms through biological process such as N fixation and solubilization of rock phosphate (Fatma *et al.*, 2006). Azotobacter and Azospirillum are one of the most important nitrogen-fixing bacteria which might be found in soil. Nitroxin is a trademark for one bio-fertilizer that includes both of these bacteria. Sokhangoy *et al.* (2012) reported that application of nitroxin increased height and yield of dill.

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Dragon's head (*Lallemantia iberica* Fisch. & C.A. Mey) is an annual short herb in the mint family (Lamiaceae). The plant has been cultivated for its seeds in Southwestern Asia and Southeastern Europe since prehistoric times. The leaves are used as a potherb in modern Iran. The seeds have been used in folk medicine as a stimulant and diuretic. *Lallemantia iberica* seeds have traditional uses as reconstitute, stimulant, diuretic and expectorant. Also, it is considered as a linseed substitute in a number of applications including: wood preservative, ingredient of oil-based paints, furniture polishes, printing inks, soap making and manufacture of linoleum (Katayoun, 2006).

Purslane (*Portulaca oleracea* L.) is an annual succulent (water content of over 90%), glabrous, prostrate, or ascending plant, 10–70 cm high, very rich branched from the base. Leaves are alternate, fleshy and obtuse apex, smooth and waxy on upper surface, margins are sometimes purple; sessile or indistinctly petiolate, 1–3 cm long, 0.5–1.5 cm wide. *Portulaca oleracea* has been reported to be the richest vegetable source of omega-3 (ω-3) fatty acids (FA) yet examined. Scientifically, purslane provides a rich plant source of nutritional benefits with high antioxidant properties. It is one of the richest green plant sources of omega-3 fatty acids. In areas where this "weed" is eaten, there is a low incidence of cancer and heart disease, possibly due to purslane's naturally occurring omega-3 fatty acids (Omara-Alwala *et al.*, 1991; Simopoulos, 2004).

The present study was undertaken to evaluate the effect of combined applications of chemical N fertilizer (urea) and nitroxin bio-fertilizer on purslane/dragon's head intercropping system.

Materials and Methods

The experiment was conducted during 2015 in the experimental farm of Agricultural Research Station of Hamadan (34° 52' N latitude, 48° 32' W longitude and 1741.5 m a.s.l.) which is located in Western Iran. The soil type was a loam soil with a pH of 7.9. The climate is moderate with an average annual precipitation of 335 mm. Cultural practices such as moldboard ploughing, disking and land leveling were done according to local practices. Field received a broadcast application of granular fertilizer including 100 kg ha-1 super phosphate triple base on the soil laboratory recommendations. Additionally, on the basis of nutrient treatments, 100 kg ha-1 urea was applied for each plot and nitroxin was inoculated into purslane and dragon's head seeds, at the time of sowing. Seeds were planted in experimental plots (2 × 3 m) at the depth of 1.5-2 cm. The distance between rows was 40 cm for purslane and 20 cm for dragon's head. In addition, the distance between seeds on rows was 10 cm for purslane and 1 cm for dragon's head in the sole cropping treatments. Sprinkle irrigation was applied to the plot area throughout the growing season.

The experiment was established as bi-factorial on the basis of a randomized complete block design with three replications. The first factor was an additive intercropping system including pure cropping of purslane, pure cropping of dragon's head, intercropping of 100% purslane + 25% dragon's head, 100% purslane + 50% dragon's head, 100% purslane + 75% dragon's head; the second factor was represented by different nutrient treatments including application of 50% inorganic N fertilizer (urea) + nitroxin, inorganic N fertilizer (urea), nitroxin and no fertilizer. In dragon's head, the distance between seeds on rows was modified to 4, 2 and 1.33 cm to create density of 25%, 50% and 75%, respectively.

At the crop maturity, in each plot an area of 1.0 m long corresponding to the central area in the middle of two rows was harvested by hand and number of branches, yield components and yield of the both crops were measured. System productivity was estimated using the relative yield total (RYT) with the following equations:

$RYT = RY_A + RY_B$

$RY\_B = Y\_bi/Y\_bm$

$RY\_A = Y\_ai/Y\_am$

Y_{ai}, Y_{am}, Y_{bi}, Y_{bm}, RY_A, RY_B and RYT are yield of species a in intercropping, yield of species for monocropping, yield of species b in intercropping, yield of species b in sole cropping, relative yield of species a, relative yield of species b and relative yield total, respectively. Data were submitted to analysis of variance considering the significance level of 5% using PROC GLM procedure in SAS software (SAS Institute, 1999).

Results and Discussion

Treatments had a significant effect on the number of branches of dragon's head and purslane. In dragon's head, the simple effect of intercropping and fertilizers was significant at 1% level and their interaction effect was also significant at the level of 1% (Table 1). In purslane simple effect of intercropping and fertilizers was significant at 1% level, but interaction effect was not significant (Table 3). As the density of dragon's head increased, the number of branches in purslane decreased (Table 3). The decrease in number of branches in high density was also reported by Martin and Deo (2000).

In both crops, the effects of treatments on capsules and nuts number were significant (Table 1 and Table 3). The highest number of nuts (2523.60 nuts m^{-2}) was observed in monocultured dragon's head with combined application of 50 kg ha^{-1} urea + nitroxin inoculation (Table 2). In purslane, the highest number of capsule per plants (1,896.46 capsules/m^{-2}) was also recorded in pure cropping of purslane with the combined application of 50 kg ha^{-1} urea + nitroxin inoculation (Table 4). This is in line with Shaalan (2005) who stated that bio-fertilizers can strongly improve the number of capsules in *Nigella sativa* L. As the density of dragon's head increased the number of capsules decreased (Table 4). This is due to the detrimental effect of competition on plants yield and growth such as consumption of environmental resources (light, water, nutritional elements).

In both crops, the effect of the treatments on one thousands seed weight was not significant (Table 1 and Table 3). This is in line with the findings of Watt and Singh (1992) who stated that lentil's seed weight was not significantly affected by crop density. Kader *et al.* (2002) reported that the effect of Azotobacter did not affect the seed weight of wheat.

In both dragon's head and purslane, effects of intercropping and fertilizers and their interaction on seed yield was significant (Table 1 and Table 2). As the density of dragon's head increased, seed yield of purslane decreased (Table 4). The highest amount of seed yield of dragon's head (172.80 g m^{-2}) was observed in monocultured dragon's head with combined application of 50 kg ha^{-1} urea + nitroxin inoculation (Table 2), while for purslane the highest amount (60.51 g m^{-2}) of this trait was in monocultured purslane with combined application of 50 kg ha^{-1} urea + nitroxin inoculation (Table 4). The same results were reported by Muoneke and Mbah (2007) and Huang *et al.* (2011). Narayan *et al.* (2013) reported that

Table 1. Number of branches, number of nuts, thousand seed yield and seed yield of dragon's head as affected by cropping systems and fertilization in the 2015 cropping seasons and ANOVA significance

Treatments	Number of branches	Number of nuts (m^{-2})	Thousand seed yield (g)	Seed yield ($g\ m^{-2}$)
MD	0.00	2021.29a	11.14a	140.67a
PD25	2.80	1278.64c	11.67a	84.24c
PD50	2.01	1599.18b	11.69a	116.73b
PD75	0.95	1673.09b	11.66a	117.21b
F1	1.74	1914.62a	11.23a	139.82a
F2	1.63	1777.54a	11.46a	128.28b
F3	1.26	1517.31b	11.85a	100.61c
F4	1.13	1362.72c	11.62a	90.13d
ANOVA				
Cropping systems (C)	**	**	ns	**
Fertilization (F)	**	**	ns	**
C×F	**	*	ns	*

Notes: MD, monocultured dragon's head; PD25, intercropping of purslane + 25% density of monocultured dragon's head; PD50, intercropping of purslasne + 50% density of monocultured dragon's head; PD75, intercropping of purslane + 75% density of monocultured dragon's head; F1, combined application of 50 kg ha-1 urea + nitroxin inoculation; F2, application of 100 kg ha-1 urea; F3, nitroxin inoculation; F4, no application of fertilizers. Means followed by the same letter(s) are not significantly different at the p = 0.05 level using Duncan's Multiple Range Test (DMRT).

Table 2. Interactive effect of cropping systems and fertilization on number of branches, number of nuts, thousand seed yield and seed yield of dragon's head in the 2015 cropping seasons

Treatments	Number of branches	Number of nuts (m^{-2})	Thousand seed yield (g)	Seed yield ($g\ m^{-2}$)
MD × F1	0.00f	2523.60a	10.54a	172.80a
MD × F2	0.00f	2291.20a	11.34a	162.97ab
MD × F3	0.00f	1733.40bcd	11.31a	120.27ef
MD × F4	0.00f	1536.90cdef	11.39a	106.67fg
PD25 × F1	3.33a	1420.90def	11.96a	92.78ghi
PD25 × F2	3.20a	1351.50fg	11.30a	89.82ghi
PD25 × F3	2.46bc	1266.00fg	11.75a	80.80hi
PD25 × F4	2.23c	1076.10g	11.67a	73.55i
PD50 × F1	2.56b	1768.50bc	11.52a	143.33bcd
PD50 × F2	2.33bc	1717.20bcde	11.43a	132.36cde
PD50 × F3	1.66d	1501.00cdef	12.27a	100.57fgh
PD50 × F4	1.50d	1410.00ef	11.53a	90.66ghi
PD75 × F1	1.06e	1945.40b	10.89a	150.400bc
PD75 × F2	1.00e	1750.30bc	11.80a	128.00de
PD75 × F3	0.93e	1568.80cdef	12.06a	100.81fgh
PD75 × F4	0.80e	1427.90def	11.88a	89.64ghi

Notes: MD, monocultured dragon's head; PD25, intercropping of purslane + 25% density of monocultured dragon's head; PD50, intercropping of purslane + 50% density of monocultured dragon's head; PD75, intercropping of purslane + 75% density of monocultured dragon's head; F1, combined application of 50 kg ha-1 urea + nitroxin inoculation; F2, application of 100 kg ha-1 urea; F3, nitroxin inoculation; F4, no application of fertilizers. Means followed by the same letter(s) are not significantly different at the p=0.05 level using Duncan's Multiple Range Test (DMRT).

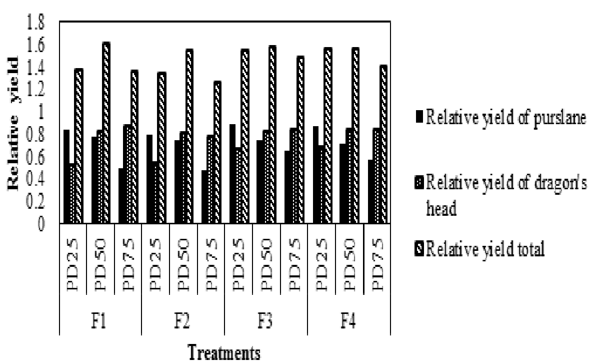

Fig. 1. The effects of cropping systems and fertilization on relative yield total of purslane/dragon's head intercropping

Notes: PD25, intercropping of purslane + 25% density of monocultured dragon's head; PD50, intercropping of purslane + 50% density of monocultured dragon's head; PD75, intercropping of purslane + 75% density of monocultured dragon's head; F1, combined application of 50 kg ha-1 urea + nitroxin inoculation; F2, application of 100 kg ha-1 urea; F3, nitroxin inoculation; F4, no application of fertilizers.

integration of microbial inoculant (*Azotobacter*) with inorganic fertilizers increased potato yield.

In the all intercropping systems, RYT was always higher than monocultured treatments (Fig. 1). The highest RYT amount of intercropping system was 1.61, which was observed in intercropping of purslane + 50% density of monocultured dragon's head with combined application of 50 kg ha^{-1} urea + nitroxin inoculation (Fig. 1). In intercropping systems, competition for environmental resources (e.g. light, water and nutrients) can decrease the yield of each individual species. However, since these species use growth resources more efficiently when they cooperate with each other, therefore, total yield in intercropping systems is often more than sole cropping.

Conclusions

On the basis of the results hereby obtained, the combination usage of nitroxin biofertilizer and inorganic N fertilizer can improve yield and yield components of both purslane and dragon's head. On the other hand, the highest

Table 3. Number of branches, number of capsules, thousand seed yield and seed yield of purslane as affected by cropping systems and fertilization in the 2015 cropping seasons and ANOVA significance

Treatments	Number of branches	Number of capsules (m^{-2})	Thousand seed yield (g)	Seed yield ($g\ m^{-2}$)
MD	4.89a	1669.59a	0.93a	48.59a
PD25	4.25b	1291.10b	0.90a	40.81b
PD50	3.44c	1091.36c	0.97a	36.37c
PD75	2.89d	1091.44d	0.90a	25.93d
F1	4.72a	1368.90a	0.94a	47.10a
F2	4.21b	1343.77a	0.90a	45.01a
F3	3.29c	1148.80b	0.92a	31.46b
F4	3.01c	1000.0c	0.93a	28.12c
ANOVA				
Cropping systems (C)	**	**	ns	**
Fertilization (F)	**	**	ns	**
C×F	**	*	ns	**

Notes: MD, monocultured dragon's head; PD25, intercropping of purslane + 25% density of monocultured dragon's head; PD50, intercropping of purslasne + 50% density of monocultured dragon's head; PD75, intercropping of purslane + 75% density of monocultured dragon's head; F1, combined application of 50 kg ha-1 urea + nitroxin inoculation; F2, application of 100 kg ha-1 urea; F3, nitroxin inoculation; F4, no application of fertilizers. Means followed by the same letter(s) are not significantly different at the p=0.05 level using Duncan's Multiple Range Test (DMRT).

Table 4. Interactive effect of cropping systems and fertilization on number of branches, number of capsules, thousand seed yield and seed yield of dragon's head in the 2015 cropping seasons

Treatments	Number of branches	Number of capsules (m^{-2})	Thousand seed yield (g)	Seed yield ($g\ m^{-2}$)
MP × F1	5.600a	1896.46a	0.96a	60.51a
MP × F2	5.33ab	1864.40a	0.90a	59.89a
MP × F3	4.60cd	1532.92b	0.94a	38.43cd
MP × F4	4.03d	1384.56b	0.92a	35.53de
PD25 × F1	5.00abc	1394.65bc	0.88a	50.99b
PD25 × F2	4.73bc	1373.53bc	0.90a	47.17b
PD25 × F3	3.16ef	1288.37c	0.91a	34.01de
PD25 × F4	3.20e	1107.84de	0.90a	31.07ef
PD50 × F1	4.36cd	1299.56c	1.03a	47.28b
PD50 × F2	4.40d	1270.05cd	0.91a	44.31b
PD50 × F3	2.90efg	986.52ef	0.92a	28.47ef
PD50 × F4	2.50fg	809.31fgh	1.01a	25.45fg
PD75 × F1	3.93d	884.90fg	0.90a	29.62ef
PD75 × F2	2.80efg	867.11fgh	0.91a	28.70ef
PD75 × F3	2.50fg	787.38gh	0.91a	24.95fg
PD75 × F4	2.33g	698.35h	0.89a	20.46g

Notes: MP, monocultured dragon's head; PD25, intercropping of purslane + 25% density of monocultured dragon's head; PD50, intercropping of purslane + 50% density of monocultured dragon's head; PD75, intercropping of purslane + 75% density of monocultured dragon's head; F1, combined application of 50 kg ha-1 urea + nitroxin inoculation; F2, application of 100 kg ha-1 urea; F3, nitroxin inoculation; F4, no application of fertilizers. Means followed by the same letter(s) are not significantly different at the p=0.05 level using Duncan's Multiple Range Test (DMRT).

RYT was observed in intercropping of 100% purslane + 50% dragon's head with the application of 50% inorganic N fertilizer (urea) + nitroxin, which indicates that application of this treatment, is more efficient than other treatments.

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