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Effects of Chemical and Biological Fertilizers on Some Morpho-Physiological Traits of Purslane (*Portulaca oleracea* L.) and Dragon's Head (*Lallemantia iberica Fisch*. & C.A. Mey) Cultivated under Intercropping System

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Abstract

Declining land productivity associated with decreasing soil organic carbon (SOC) and nitrogen (N) are significant issues in monoculture crop production. In addition, continuous use of inorganic fertilizer often leads to unsustainability in crop production and creating environmental pollution. Considering the importance of purslane (*Portulaca oleracea* L.) and dragon's head (*Lallemantia iberica* Fisch. & C.A. Mey) in human nutrition, a field study was carried out to assess the effects of chemical and biological fertilizers on purslane-dragon's head intercropping. The factorial experiment was set on the basis of randomized complete block design with three replications. The first factor was an additive intercropping system including monocropping of purslane (P), monocropping of dragon's head (D), intercropping of 100% purslane + 25% dragon's head (PD25), intercropping of 100% purslane + 50% dragon's head (PD50), intercropping of 100% purslane + 75% dragon's head (PD75); the second factor was nutrient treatments including application of 50% inorganic N fertilizer (urea) + nitroxin (F1), inorganic N fertilizer (urea) (F2), nitroxin (F3) and no fertilizer (F4). For purslane crop, the highest amount of relative chlorophyll (SPAD) belonged to PD75 + F1 treatment. Intercropping increased stem height of both crop plants. The data obtained hereby clearly showed that the total yield of the purslane-dragon's head intercropping treatments was higher than any of the monocropping treatments. PD50 + F1 had the highest amount of land equivalent ratio (LER). Therefore, intercropping of 100% purslane + 50% dragon's head and application of 50% urea + nitroxin might be recommended for higher yield and economic return.

Keywords: monocropping, nitroxin, relative chlorophyll, stem height, yield increasing rate

Introduction

Intercropping, or the simultaneous cultivation of different species plants in the same field, is a world-wide agricultural practice. It has the potential to increase the grain yields of plants and this efficiency has been attributed to the enhanced utilization of space, time, light (Muoneke and Mbah, 2007; Zhang *et al.*, 2008) and water (Jahansooz *et al.*, 2007). Intercropping is considered an important strategy in developing sustainable production systems, particularly systems that aim to limit external inputs (Adesogan *et al.*, 2002).

Continuous use of inorganic fertilizer often leads to unsustainability in crop production and creates deficiency of certain nutrients in the soil as well as environmental pollution. In response to these concerns, there are worldwide concerted efforts to use organic manures and bio-fertilizers to produce the same amount of food with less inorganic fertilizer. In Iran, integrated nutrients supply to plants through bio-fertilizer and inorganic sources is becoming an increasingly important aspect of environmentally sound sustainable agriculture (Meelu *et al.*, 1994).

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). Nowadays, sustainable nitrogen (N) management is particularly challenging because of increasing costs of mineral N fertilizers, coupled with N fertilizer's emission of nitrous oxide (N_2O) and nitrate's potential to contaminate both ground and surface water (Ferguson *et al.*, 1999). This challenge suggests that more effort is needed to develop sustainable and ecologically sound nutrient management practices that are scalable to large farms. For small crop production, one strategy that addresses many of these concerns is the inclusion of biological fertilizers under crop production practices.

Biological fertilizers represent a specific complex of microorganisms that mobilize main nutrients from unavailable forms into available ones and can improve root system and seed

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germination. *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. Same results were reported by Fatma *et al.* (2006) on marjoram. In addition, there are worldwide concerted efforts for the use organic manures and bio-fertilizers to produce the same amount of food with less inorganic fertilizer. Currently, integrated nutrients supply to plants through bio-fertilizer and inorganic sources is becoming an increasingly important aspect of environmentally sound sustainable agriculture (Meelu *et al.*, 1994). Therefore, effects of bio-fertilizers in combination with inorganic fertilizers on the growth and yield of crops and soil health need to be better understood.

Purslane (*Portulaca oleracea* L.) is an annual succulent in the family Portulacaceae of which approximately forty varieties are currently cultivated. Although purslane is considered a weed, it may be consumed as a leaf vegetable. In Iran its leaves are used to make pickle and its seed are used in pastry. Purslane contains more omega-3 fatty acids (alpha-linolenic acid in particular) than any other leafy vegetable plant. It also contains vitamins (mainly vitamin A, vitamin C, vitamin E (alpha-tocopherol), vitamin B, carotenoids) and dietary minerals such as magnesium, calcium, potassium and iron. It contains two types of betalain alkaloid pigments, the reddish betacyanins (visible in the coloration of the stems) and the yellow betaxanthins (noticeable in the flowers and in the slight yellowish cast of the leaves). Both of these pigment types are potent antioxidants and have been found to have antimutagenic properties in laboratory studies (Liu *et al.*, 2000; Simopoulos, 2004).

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).

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.

Materials and Methods

The experiment was conducted during 2014 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 8.05. 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 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 monocropping 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 (P), pure cropping of dragon's head (D), intercropping of 100% purslane + 25% dragon's head (PD25), intercropping of 100% purslane + 50% dragon's head (PD50), intercropping of 100% purslane + 75% dragon's head (PD75); the second factor was represented by different nutrient treatments including application of 50% inorganic N fertilizer (urea) + nitroxin (F1), inorganic N fertilizer (urea) (F2), nitroxin (F3) and no fertilizer (F4). 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.

To determine the trend of the relative chlorophyll (SPAD) during the growing season, 15 days after crop emergence (DAE), SPAD value was evaluated using SPAD-502 device and then it was repeated 6 times within 10 days interval. Additionally, crop sampling was done several times during the growing season to determine the height of plants. In each sampling both purslane and dragon's head plants were cut at the soil surface and their height was measured. To quantify plant height over time as influenced by intercropping and nutrients, data were regressed on time (day after emergence) using Richards function (Hunt, 1982):

$$Y = \frac{Y_{\max}}{\left[1 + \exp(a - b \times T)\right]^{1/c}}$$

Where, Y_{max} represents maximum height, a, b, and c are shape coefficients, and T is days after emergence of crop.

The purslane and dragon's head plants were harvested when matured and then seed yields were measured. System productivity was estimated using the land equivalent ratio (LER) which compares the yield obtained by intercropping two or more species together with yields obtained by growing the same crops as monocultures (Mead and Willey, 1980):

$$LER = \frac{intercrop\ yield_{purslane}}{monocrop\ yield_{purslane}} + \frac{intercrop\ yield_{dragon's\ head}}{monocrop\ yield_{dragon's\ head}}$$

In addition, yield increasing rate was calculated as follows:
Yield increasing rate = (LER-1) x 100

To evaluate the effect of treatments on height of purslane and dragon's head, equations were fitted to the data for each treatment, using PROC NLIN procedure. Furthermore, yield data were submitted to analysis of variance considering the significance level of 5% using PROC GLM procedure in SAS software (SAS Institute, 1999) and then, means comparison using Duncan's Multiple Range Test (DMRT) was performed.

Results and Discussion

During the growing season, within the most treatments, SPAD value of both purslane and dragon's head, gradually increased and reached the maximum amount approximately at the middle of the growing season. Afterwards, because of aging and chlorophyll decomposition of old leaves, SPAD value gradually decreased (Fig. 1 and Fig. 2). In both crops, the highest value of SPAD belonged to PD75 + F1, with the amount of 47.13 for purslane and 46.43 for dragon's head (Fig. 1a and Fig. 2a). This is in line with Magdi *et al.* (2003) results. In intercropping systems, due to high density and shading, plants increase their chlorophyll pigments to absorb light with high efficiency. In addition, a proper supply of nitrogen, as the application of 50% urea + nitroxin (F1), can help plants to build up more chlorophyll contents (Magdi *et al.*, 2003).

Regardless of the intercropping and nutrient treatments imposed, stem height of both purslane and dragon's head increased during the growing season and reached to its maximum point 60 days after crops' emergence (Fig. 3 and Fig. 4). Compared to other treatments, both crops had the highest stem height in PD75 + F1 treatments (46.22 cm for purslane and 30.11 cm for dragon's head respectively) (Fig. 3a and Fig. 4a), while the lowest values (27 cm for purslane and 16.65 cm for dragon's head) were observed in monocropping + F4 (P + F4 and D + F4 treatments) of both plants (Fig. 3d and Fig. 4d). Okpara (2000) reported that intercropping maize and cowpea, the height of cowpea increased. It is suggested that the increase in plant height under high density of plants is the result of an increase in far-red radiation compared to red radiation in consequence of shading (Rohrig and Stutzel, 2001). Smith (1986) concluded that the effects of shading on stem elongation were due to increased cell elongation, as no changes occurred in the rates of cell division or node formation. Youssef *et al.* (2004) reported that *Azotobacter* and *Azospirillum* inoculation increased the height of *Salvia officinalis*. Larsen *et al.* (2009) stated that bio-fertilizers can increase plant height due to diverse mechanisms such as production of phytohormones and ACC deaminase enzyme. Some bacteria generally entails facilitating the acquisition of nutrient resources from the environment including fixed nitrogen, iron and phosphate, or in specifically modulating plant growth by altering plant hormone levels such as auxin, cytokinin and ethylene (Glick, 2014).

Treatments had a significant effect on seed yield of purslane and dragon's head. In both crops, simple effect of intercropping and fertilizers was significant at 5% level and their interaction effect was also significant at the level of 1% (Table 1). As the density of dragon's head increased, seed yield of purslane decreased (Fig. 5).

For purslane, the highest amount of seed yield (57.07 g m^{-2}) was observed in P + F1 (Fig. 5), while for dragon's head the highest amount (154.23 g m^{-2}) of this trait was within D + F1 treatments (Fig. 6). This data were in line with the findings of Li *et al.* (2005), Muoneke and Mbah (2007) and Huang *et al.* (2011). In intercropping systems, competition for capture of the plant growth resources (e.g. light, water and nutrients) can decrease the yield of each individual species. However, since these species together can use growth resources more efficient, therefore, total yield in intercropping systems is often more than the one obtained when monocropping. In accordance with the hereby findings, Narayan *et al.* (2013) reported that integration of microbial inoculant (*Azotobacter*) with inorganic fertilizers increased potato yield. Similar results have also been reported by Singh and Gupta (2005).

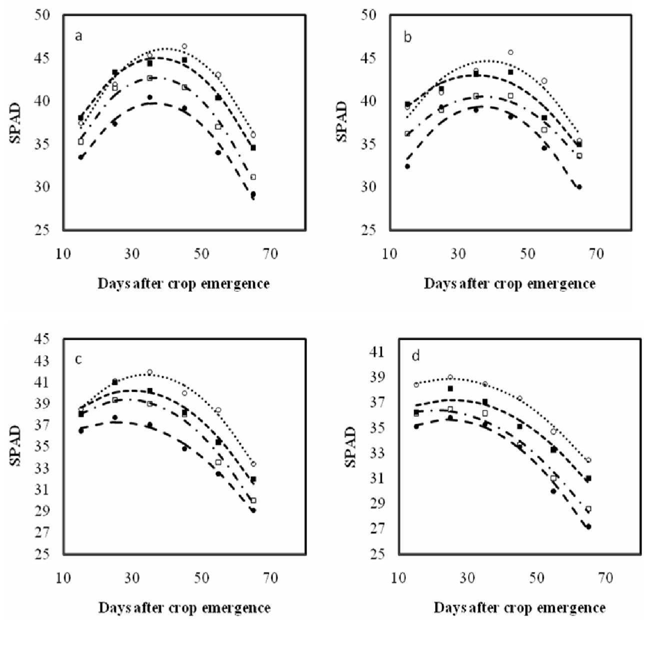

Fig. 1. Effects of the application of 50% urea + nitroxin (a), urea (b), nitroxin (c) and no fertilizer (d) and monocropping (solid circles), intercropping of 100% purslane + 25% dragon's head (empty squares), intercropping of 100% purslane + 50% dragon's head (solid squares), intercropping of 100% purslane + 75% dragon's head (empty circles) on relative chlorophyll (SPAD) of purslane; dots and lines are observed data and regression respectively

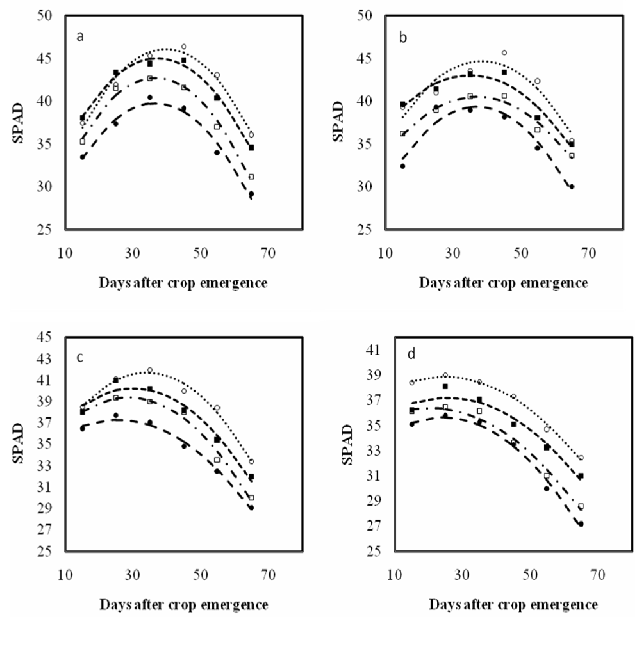

Fig. 2. Effects of the application of 50% urea + nitroxin (a), urea (b), nitroxin (c) and no fertilizer (d) and monocropping (solid circles), intercropping of 100% purslane + 25% dragon's head (empty squares), intercropping of 100% purslane + 50% dragon's head (solid squares), intercropping of 100% purslane + 75% dragon's head (empty circles) on relative chlorophyll (SPAD) of dragon's head; dots and lines are observed data and regression respectively

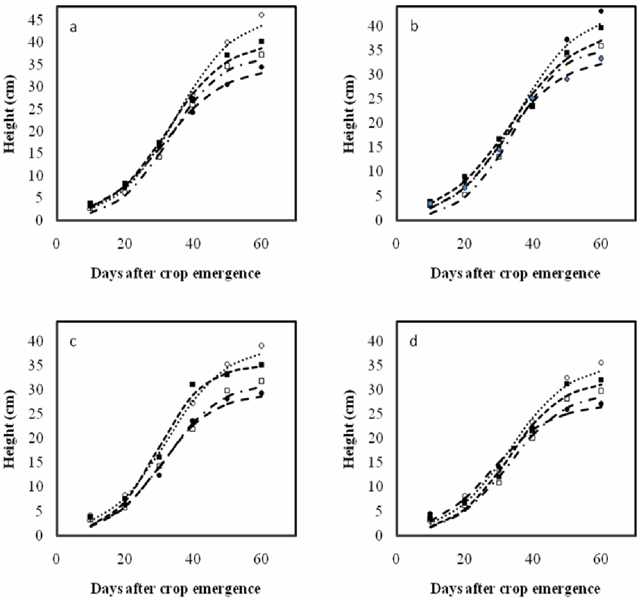

Fig. 3. Effects of the application of 50% urea + nitroxin (a), urea (b), nitroxin (c) and no fertilizer (d) and monocropping (solid circles), intercropping of 100% purslane + 25% dragon's head (empty squares), intercropping of 100% purslane + 50% dragon's head (solid squares), intercropping of 100% purslane + 75% dragon's head (empty circles) on stem height of purslane; dots and lines are observed data and regression respectively

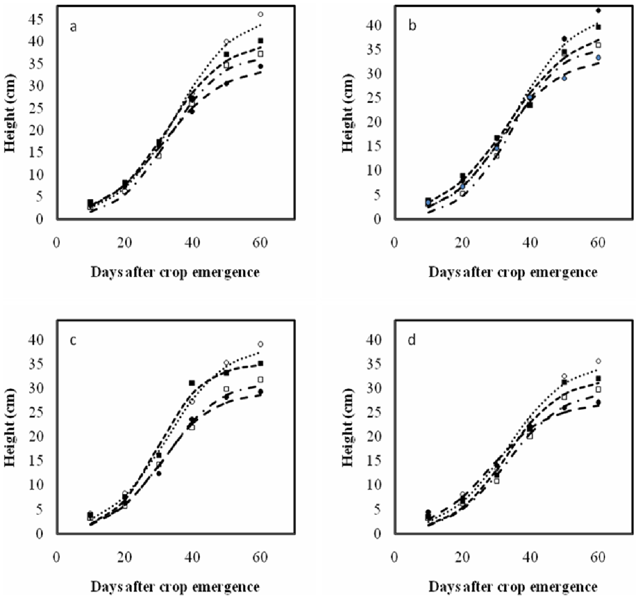

Fig. 4. Effects of the application of 50% urea + nitroxin (a), urea (b), nitroxin (c) and no fertilizer (d) and monocropping (solid circles), intercropping of 100% purslane + 25% dragon's head (empty squares), intercropping of 100% purslane + 50% dragon's head (solid squares), intercropping of 100% purslane + 75% dragon's head (empty circles) on stem height of dragon's head; dots and lines are observed data and regression respectively

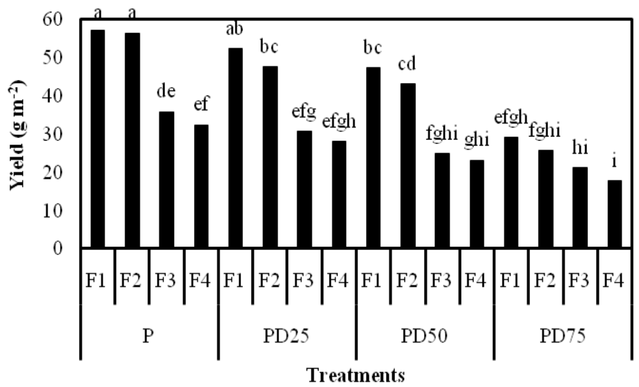

Fig. 5. Interaction effects of intercropping and fertilizers on seed yield of purslane; F1: application of 50% urea + nitroxin, F2: urea, F3: nitroxin, F4: no fertilizer; P: purslane monocropping, PD25: intercropping of 100% purslane + 25% dragon's head, PD50: intercropping of 100% purslane + 50% dragon's head, PD75: intercropping of 100% purslane + 75% dragon's head

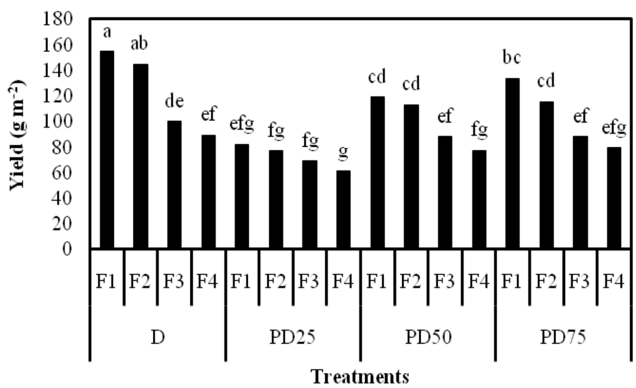

Fig. 6. Interaction effects of intercropping and fertilizers on seed yield of dragon's head; F1: application of 50% urea + nitroxin, F2: urea, F3: nitroxin and F4: no fertilizer; D: dragon's head monocropping, PD25: intercropping of 100% purslane + 25% dragon's head, PD50: intercropping of 100% purslane + 50% dragon's head, PD75: intercropping of 100% purslane + 75% dragon's head

As shown in Fig. 7, the land equivalent ratio (LER) in intercropping system was significantly higher than that in the monocropping treatments. The highest LER amount of intercropping system was 1.60 in PD50 + F1 treatments. The obtained data clearly showed that the total yield of the purslane-dragon's head intercropping treatments was higher than any of the monocropping treatments. This was in line with Rezvani Moghaddam and Moradi (2012) who reported that LER of cumin-fenugreek intercropping was higher than the yields obtained by monocropping these species. Additionally, they stated that application of biological fertilizer can increase yield and LER of the plants.

The highest amount of yield increasing rate 59.81% was recorded in PD50 + F1 treatment (Fig. 8). This means that PD50 + F1 treatment had more total yield than the other treatments. Same results were reported by Qin *et al.* (2013). Yield advantages from intercropping are often attributed to complementation between component crops in the mixture,

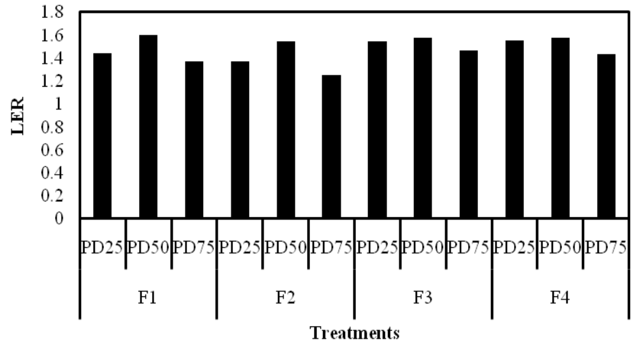

Fig. 7. Land equivalent ratio (LER) of purslane-dragon's head intercropping under different fertilizer treatments; F1: application of 50% urea + nitroxin, F2: urea, F3: nitroxin and F4: no fertilizer; PD25: intercropping of 100% purslane + 25% dragon's head, PD50: intercropping of 100% purslane + 50% dragon's head, PD75: intercropping of 100% purslane + 75% dragon's head

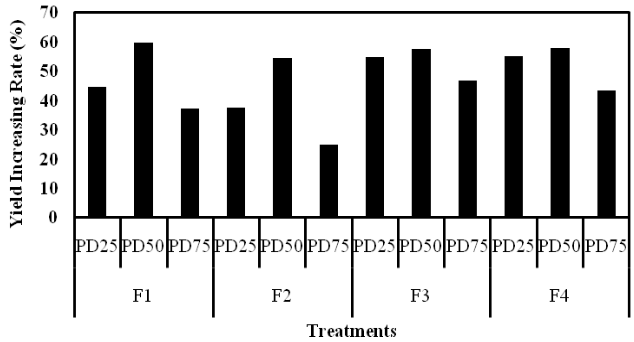

Fig. 8. Yield increasing rate (%) of purslane-dragon's head intercropping under different fertilizer's treatments; F1: application of 50% urea + nitroxin, F2: urea, F3: nitroxin and F4: no fertilizer; PD25: intercropping of 100% purslane + 25% dragon's head, PD50: intercropping of 100% purslane + 50% dragon's head, PD75: intercropping of 100% purslane + 75% dragon's head

Table 1. Analysis of variance for yield of purslane and dragon's head as affected by intercropping schemes and fertilizer treatments

S.O.V	DF	Means squares	
		$Yield_{Purslane}$	$Yield_{Dragon's\ head}$
Replication	2	3.00^{ns}	69.45^{ns}
Intercropping (I)	3	$1,057.58^{**}$	$5,072.58^{**}$
Fertilizers (F)	3	$1,347.97^{**}$	5513.55^{**}
I × F	9	48.28^{*}	304.79^{*}
C.V. (%)		12.85	11.71

ns, *, **: non-significant, significant at 5% and 1% level probability level, respectively

resulting in a better total use of resources when growing together rather than separately (Blaise *et al.*, 2005).

Conclusions

The data obtained hereby clearly showed that the total yield of the purslane-dragon's head intercropping treatments was higher than any of the monocropping treatments, thus concluded in a better total use of resources when growing together rather than separately. Based on the current results, intercropping of 100% purslane + 50% dragon's head and application of 50% urea + nitroxin might berecommended for higher yield, LER and economic return per unit area for the two crops cultivated under the temperate climate.

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