FORAGE YIELD IMPROVEMENT AT PROPER RATIO AND SEED DENSITY OF SMOOTH VETCH AND BARLEY MIX CROPPING UNDER COLD RAIN-FED CONDITIONS

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ABSTRACT

The mixing ratios of barley (Hordeum vulgare L.) cv. Abidar and smooth vetch (Vicia dasycarpa L.) cv. Maragheh were studied at Dryland Agricultural Research Institute under cold rain-fed conditions during 2009-2011 growing seasons. The mix cropping treatments comprised of pure vetch, vetch with barley at 3:1, vetch with barley at 1:1 seeding ratio and pure barley. There was one seeding rate (100 seeds m⁻²) for barley and five different seeding rates of vetch including 100, 150, 200, 250, 300 seeds m⁻² (D₁, D₂, D₃, D₄, D₅). Higher dry matter (DM) yields were obtained across different seed rates for the vetch mixtures than related monocultures. The highest DM and the lowest protein content over years were obtained from pure barley. The combination of vetch with barley at 1:1 seeding ratio in the D₅ density produced 16 ton ha⁻¹ dry forage and 1 ton ha⁻¹ protein. The highest land equivalent ratio over two years (1.44) was belonged to mixture of vetch with barley at 3:1 ratio in D₅ seeding rate. It was concluded that, mixture of vetch with barley at 1:1 seeding ratio in D₅ smooth vetch density was the best mixing ratio and seed density regarding both forage quality and quantity under cold rain-fed conditions.

Key words: Bi-culture; highlands; Hordeum vulgare; Vicia dasycarpa.

INTRODUCTION

The resource base of dryland agriculture is experiencing increasing pressure due to rapidly growing human population and demands for livestock (Alizadeh and da Siva, 2013). About three quarters of extremely poor farmers are estimated to keep livestock as part of their livelihood portfolios, safeguarding and increasing the returns from their livestock assets is expected to help them in their endeavor to escape poverty (FAO, 2010).

Drylands occupy about 6.2 million hectares across Iran, which are mainly used for wheat and food legumes production. About 2-3 million hectares of arable lands are left as fallow every year (Alizadeh, 2010). Considerable variation has been reported in herbage and grain yields of improved vetches (Vicia spp.) under Iranian rain-fed conditions. Introduction of annual feed legumes in dryland cropping systems that are dominated by cereals would reduce pest and disease risk and increase sustainable productivity. Dhima et al. (2007) reported that there was an advantage of intercropping for exploiting the resources of the environment.

Mixtures of annual feed legumes with winter cereals have greater potential for forage production in the rain-fed conditions (Lithourgidis et al., 2006). Pure stands of most feed legumes are damaged during winter in autumn planting under cold dryland conditions and monocultures of feed legumes as spring crop do not provide remarkable results for forage production in highlands (Alizadeh and da Siva, 2013). On the other hand, winter cereals provide high yields in terms of dry weight but they produce forage with low protein and the forage quality of cereal hay is generally lower than that required to meet production goals for many livestock classes (Lawes and Jones, 1971). In legume-cereal mixtures, companion cereals provide structural...
support for legumes, improve light interception, and facilitate mechanical harvest, meanwhile legumes in mixtures improves the quality of forage (Thompson et al., 1992). Other benefits of mixtures include greater uptake of water and nutrients, enhanced weed suppression, and increased soil conservation (Anil et al., 1998).

Competition between mixture components may affect yield and quality of forage produced by mixtures (Caballero, 1995). Competition normally reduces yield of mixtures compared with cereal monocultures (Caballero, 1995), although higher yields have been reported when competition between the two species of the mixture was lower than competition within the same species (Vandermeer, 1989). The species from both cereals and legumes which are used in mixtures have different competitions and interaction level. Caballero et al. (1995) reported that the most suitable cereal for mixtures with common vetch is oat (Avena sativa L.), whereas Roberts et al. (1989) reported that barley and wheat are the most suitable cereals for mixtures. Anil et al. (1998) reported that triticale can be used as an alternative cereal for mixtures with common vetch. Seeding ratios are another affecting factor in competition between the two species of the mixture (Caballero et al. 1995). Lithourgidis et al. (2006) reported that the mixture of common vetch with oat at the 65:35 seeding ratio gave the highest forage yield. Despite the fact that competition is one of the factors that can affect forage yield and quality there are no reports on the effect of different cereals and different seeding rates on the growth rate of legume–cereal mixtures. Competition can also have a significant effect on growth rate of the different species used in mixtures (Ghosh, 2004).

Several functions or parameters have been used to assess the efficiency of intercrops (Vandermeer, 1989). However, the most basic tool that agricultural scientists generally use to evaluate the intercrop efficiency of grain yield, dry matter, and mass density of a crop with respect to sole crops is the land equivalent ratio (LER). Relative value total (RVT) recognizes the importance of the economic value of the crops, and defines an advantage for the intercrop only if the economic value of the mix crop is greater than the economic value of the highest yield in mono culture. The intercrop then exceeds yields economically if RVT $> 1$.

Various ratios have been reported in different mix croppings for high biomass, including rye with vetch at 2:1 ratio (Clark et al., 1997), triticale (Triticosecale) with vetch at 9:1 ratio (Sebahattin et al. 2004) and oat with vetch at 7:3 ratio (Lithourgidis et al., 2006). This differences in seeding ratios could have been because of the species of grass and legume in the mix cropping as well as different soil properties and climatic conditions in the research regions. Alizadeh and da Silva (2013) reported that autumn seeding of smooth vetch (cv. Maragheh) and barley (cv. Abidar) in 1:1 ratio produces considerable forage in terms of quantity and quality. They concluded that mixture of barley and smooth vetch in 1:1 ratio could be a suitable alternative crop after wheat or barley in cold and semi-cold dry land. However, the appropriate legume seeding rates for this purpose have not yet been explored under cold highland conditions. The objective of the present work was to evaluate biomass yield and protein content in some mixtures of barley with smooth vetch at different seed rates along with pure stands under cold dryland conditions.

**MATERIALS AND METHODS**

Smooth vetch (Vicia dasycarpa L.) cv. Maragheh and barley (Hordeum vulgare L.) cv. Abidar were studied at Dryland Agricultural Research Institute (DARI) during two years (2009-2010 and 2010-2011) in the North-west Iran (37° 15': N, 46° 20': E and 1720 meters above the sea levels). The soil type was Rajal Abad fine Mixed Mesic Calcixerollic Xero Chrepts based on USDA soil taxonomy. The intercropping treatments comprised of 100% smooth vetch, 75% smooth vetch+ 25% barley, 50% smooth vetch+ 50% barley and 100% barley. There was one seeding rate (100 seeds m$^{-2}$) for barley and different seed densities of smooth vetch including 100, 150, 200, 250, 300 seeds m$^{-2}$ which designed as D$_1$, D$_2$, D$_3$, D$_4$ and D$_5$ respectively.

Experimental fields were prepared by chisel in the end September 2009 and 2010 which followed by replacement of appropriate N-P fertilizer where, 40 kg ha$^{-1}$ N and 20 kg ha$^{-1}$ P$^2$O$_5$, was uniformly applied to the soil.

Hays were harvested when legume plants reached the beginning of the pod formation stage. Sub-samples were dried at 70°C for 48 h to determine
dry matter yield. Nitrogen content of hay was determined on the same dried sub-samples by micro-
Kjeldahl procedure described by Nelson and Sommers (1980), and crude protein concentration was calculated \((N \times 6.25)\). Association of Analytical Communities (AOAC) official methods (1980) were used for measuring potassium (K) and phosphorous (P).

The land equivalent ratio (LER) was calculated according to Willey (1979):

\[
LER = \frac{P_1}{M_1} + \frac{P_2}{M_2}
\]

where, \(P_1\) and \(P_2\) are the yields of two different crops in intercropping and \(M_1\) and \(M_2\) are the yields of these crops in mono-cropping. Relative value total (RVT) was estimated by the following equation (Vandermeer, 1989):

\[
RVT = \frac{(aP_1 + bP_2)}{aM_1}
\]

where \(P_1\), \(P_2\) and \(M_1\) are defined as in the LER equation, and \(a\) and \(b\) are the market prices of crops 1 and 2, respectively.

Statistical analyses were conducted using SPSS software and the means were compared using Duncan’s multiple range (DMRT) test at \(\alpha = 0.01\) following analysis of variance.

**RESULTS AND DISCUSSION**

Based on the combined analysis of results, there were significant differences between planting ratios regarding all studied characteristics in the mixed smooth vetch and barley (Table 1). Effect of years and treatment by year interaction was not significant in this study (Table 1). The mean of all traits were higher in the second year (The means were not shown). This may be due to suitable temperatures and distribution of annual precipitation during 2010-2011 comparing the first year (Fig. 1).

The highest dry matter was obtained with pure stands of barley that was not significantly different from 50:50 smooth vetch:barley ratio over years (Fig. 2). Sole cropping of smooth vetch produced the lowest dry matter, without any difference at different seeding rates (Fig. 2).

In general, all mixtures produced more nitrogen (N), phosphorous (P) and potassium (K) in the both years comparing pure stands (Fig. 3 and Fig. 5), which is an indicative of a synergetic interaction between two crops, when are sown together, leading to exploitation more resource. The superior planting ratio regarding P and K was 50:50 ratio of smooth vetch-barley, which also produced the highest crude protein (Fig. 4 and Fig. 5). Increasing barley ratio in mixture caused more P and K in second year relative to first year; however, in both years, vetch pure stand produced more total P and K than pure barley, showing more efficiency of vetch to acquire nutrients from soil. Then, reducing vetch in mixture more than 50% caused a striking reduction in nutrient absorption (Fig. 4 and Fig. 5). The similar trend also was observed for crude protein. It can be concluded that barley could benefit from more suitable condition in second year, but smooth vetch showed more stability in nutrient absorption and protein production, with higher amounts in both years. Many studies also have declared on advantages and economical aspects of mixed and intercropping than pure stands, especially for forage production (Abbas et al., 2001). Osman and Osman (1982) studied mixtures of sorghum and a legume (Dolichos lablab L.) forage in the Sudan and observed that the highest yield was reached with 1:1 ratio of cereal-legume. Posler et al. (1993) evaluated compatibility of grass-legume mixture and stated almost all mixtures attained more yields than monocultures of grasses.

Crude protein content of produced forage is one of the most important criteria to measure forage quality. It is proven that legumes are richer in protein,

| TABLE 1: Combined analysis of variance regarding potassium (K), phosphorus (P), dry matter (DM) and crude protein (CP) for mix cropping of smooth vetch and barley during 2009-2011. |
|-----------------|------|------|------|------|------|
| S.O.V          | d.f. | K    | P    | CP   | DM   |
| Year (Y)       | 1    | 0.7ns| 0.1ns| 1.94ns| 0.00004ns |
| Rep/Y          | 4    | 20.1 | 2.8  | 0.0001| 0.00004 |
| T              | 15   | 77.1**| 9.7**| 0.005**| 0.005** |
| T x Y          | 15   | 0.2ns| 0.1ns| 0.00001ns| 0.00002ns |
| Error          | 60   | 5.1  | 0.6  | 0.00005| 0.0004 |


Figure 1: Two years (2009-2011) monthly precipitation (mm) data of experimental site, Maragheh, Iran

Figure 2: Mean dry matter production over two years (2009-2011) in different mixtures of smooth vetch and barley at different seed density. Means followed by the same letters are not significantly different according to DMRT ($P = 0.05$) across all treatments.

Figure 3: Mean protein content over two years (2009-2011) in different mixtures of smooth vetch and barley at different seed density. Means followed by the same letters are not significantly different according to DMRT ($P = 0.05$) across all treatments.

Figure 4: Mean phosphorus percent over two years (2009-2011) in different mixtures of smooth vetch and barley at different seed density. Means followed by the same letters are not significantly different according to DMRT ($P = 0.05$) across all treatments.

whereas grasses have a higher carbohydrate content and their forage quality is too low to meet satisfactory production of many animal groups (Thompson et al., 1992). Therefore, concerning the relative low protein content of cereals and animal requirements for balanced feed, the importance of mixed cereal-legume cropping would be more critical (Karadag and Buyukburc, 2004). Similar to our results, Osman and Osman (1982) also found the highest and the lowest crude protein percentage in legume and cereal sole cropping, respectively and as legume ratio increased in mixture, protein percentage of mixture forage was improved. Posler et al. (1993) reported all legumes enhanced forage crude protein in mixture compared to cereals sole cropping, as also was observed by others in inter-and mixed cropping of different legume and grasses species (Lithourgidis et al., 2006; Abbas et al., 2001).

Land Equivalent Ratio (LER) was used to assess profitability of mixtures relative to sole cropping of two crops in respect to dry forage and crude protein (Table 2). LERs of $> 1$ were obtained in some mixed treatments, showing higher advantage and land use efficiency in them compared...
with sole cropping and the highest LERs for forage production and crude protein percent was obtained with 50:50 planting in both years (Table 2). These results again confirmed that mixed cropping generally produce more yield per area than its related pure stands. Marshall and Willey (1983) studied pearl millet-groundnut intercropping and found based on LER (1.28), when crops were intercropped, 28% more dry forage was produced relative to their sole cropping. This additional yield can be attributed to reduction of whole competition as a result of declined inter species competition in related mixture. Indeed, differences in crops architecture and form can increase radiation penetration through canopy and therefore increase optimum plant density of mixture.

The RVT values of some treatments were greater than one (Table 2) meaning that some intercropping resulted in economic advantage. The highest RVT were 1.12 and 1.22, indicating 12 and 22% economic advantage for related mixtures in this research. Therefore, mix cropping of smooth vetch with barley could considerably increase economical revenues and the profitability of the farmlands. Alabi and Esobhawan (2006) reported 10% higher profit based on relative value of intercropping index in maize-okra intercrop compared to mono-crops. Intercropping of maize-groundnut produced higher LER and monetary advantage (>1) than sole crops (Ghosh, 2004).

Results from these two-years mixed cropping studies indicated that intercropping of smooth vetch and barley in proper ratio could increase land productivity and forage production and enhance feed nutrient composition. Thus, using cereal-legume mixed crops, such as barley and smooth vetch can enhance dry season feed availability, leading to more sustainability of low-input and traditional agricultural systems, as well as modern and organic agro-ecosystems. Of course, screening for more suitable legumes is required to supply valuable forages in semi-arid regions, as well as to gain other advantages from legumes, for example soil conservation and N fixation, with introducing them into the cropping systems of these areas.

REFERENCES


