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Effect of Variable Sowing Ratios and Sowing Rates of Bitter Vetch on the Herbage Yield of Barley-bitter Vetch Mixed Cropping

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Abstract: Field trials were carried out at the Jordan University of Science and Technology in Northern Jordan to determine whether mixtures of bitter vetch with barley would change vetch and total yield in a competitive or facilitative way related to sowing proportions based on number of seeds. Ratios of the number of vetch to barley seed were 100:0; 85:15; 70:30; 65:45 and 40:60 within each mixture, sowing rates of bitter vetch were 80, 100, 120 and 140 kg ha^{-1}. The barley was sown at 150 kg ha^{-1}. Plants were harvested at the pod setting stage of vetch. Relative yield total of both crops was used as the parameter for mixed stand advantage. Mixed cropping produced 96% more dry matter than the sole cropping of vetch, but 63% less than the barley sole cropping. Mixed cropping yields were not simulated by sowing ratio or sowing rate of vetch but proportions of vetch dry matter decreased linearly as the percentage of barley seed in the mixture increased. The data suggested the possibility of greatest vetch yield with barley proportions below 15%. If high herbage yield is the objective, the barley sole crop will be selected. Crude protein content regardless of herbage yield should not be a criterion to define the best sowing rate of barley-vetch mixture. High forage quality of the mixed cropping would require a very low sowing proportion of barley to increase vetch contribution to forage yield

Key words: Sole cropping, mixed cropping, *Vicia ervilia, Hordeum*

Introduction

Forage legumes can play an important role in sustaining the productivity of the barley-based farming system in the Mediterranean countries especially under semiarid environment. Their ability to symbolically fix nitrogen and improve soil structure in the barley-dominated farming system is key to the system's sustainability (Turk, 1997). However, their most important condition is to provide feed for the livestock-based arid and semiarid parts of the region. An adapted forage legume can replace fallow in the traditional barley-fallow crop rotation. Integrating winter annual legumes into crop rotations has been recommended as a means of reducing the use of nonrenewable resources (Hargrove, 1986). When cut green, an adapted forage legume can use available soil moisture very efficiently and produces valuable dry matter necessary for livestock feed. *Vicia* species appeared to be a highly promising forage legume, which fits the long-term objective of integrating crop and livestock production. The availability of forage legumes allows livestock production to be integrated into the farming system and relieve pressure on overgrazed and seasonally available rangeland (Caballero *et al.*, 1992).

Bitter vetch [*Vicia ervilia* (L.) Willd.] is one of the most forage legume crops used for seed and high quality hay in the semi-arid regions (Turk, 1999). Vetch species including bitter vetch, used for haymaking have a scrambling habit, which results in rotting and harvesting difficulties when grown as pure stand. Mixture of vetch and small grain cereals are often planted for haymaking. Barley seems to be the most suitable companion crop for bitter vetch in the semiarid regions of the Mediterranean basin. It provided support for the climbing vetches, improved light interception and facilitating mechanical harvesting. A balanced botanical composition is needed, however, because legumes are of paramount importance to the nutritive value of the forage mixture (Thomson *et al.*, 1990). There is considerable evidence of the merits of growing barley and vetch, the two most important cultivated forage crops of the semiarid regions of the world (Ababneh, 1983). Over-yielding in mixture may occur when competition between species is less intense than between member of the same species (Caballero *et al.*, 1995). Population density can determine the amount of competition or facilitation in species mixtures (Vandermeer, 1990). Barley-vetch mixtures in Jordan yielded an average of 28 to 38% more than a pure stand of either barley or bitter vetch (Ababneh, 1983).

The objective of this study was to compare the yields from mixed stands of bitter vetch (main crop) and barley (subsidiary crop) obtained when several sowing rates of vetch were combined with various sowing ratios of the two crops.

Materials and Methods

Field trials were carried out in the main growing seasons (November - June) of 1997-98 and 1998-99 on a site at the Jordan University of Science and Technology campus (JUST) in Northern Jordan (32° 34' N latitude; 36° 01' E longitude; and 520 m altitude). The JUST location has a Mediterranean climate and typically experiences moderate to severe drought stress during the seed-fill period. The soil at this site is smectitic, thermic, typic chromoxererit, very fine with a clay texture in the 15-cm below the soil surface. The pH in this horizon is 8.1, and organic matter is 16 g (kg/ soil). The plots were sown by hand in the second half of November using recommended cultivation practices. Prior to plow approximately 100 kg diammonium phosphate (N 18%, P_2O_5 46%) ha^{-1} was broadcast on the experimental plots. Supplementary irrigation of a total of 30 mm was applied as required throughout the course of the trial. Weeds were removed by hand as necessary.

The treatments were arranged as a factorial combination of four levels of the principal crop (bitter vetch) sowing rates (80, 100, 120 and 140 kg ha^{-1}) and five levels of sowing proportions (0, 15, 30, 45 and 60 %) of the secondary species (barley) seed numbers. Corresponding barley-sowing densities for each combination are shown in Table 1. Seed weights of the crops were 52.1 and 43.2 mg for vetch and barley, respectively.

Pure stand barley was included at the sowing rate of 150 kg ha^{-1} and randomized within the treatment structure. Plots (2 x 7m^2) were arranged in a randomized complete block design with three replications.

Seed of both crops were hand-broadcast and covered by light spike tooth harrow in both growing seasons, pure stand and mixture were sown on November 12 and 19 and harvested in May 20 and 26 of the following year, respectively. Bitter vetch and barley were harvested at pod setting and anthesis, respectively. The barley (CV. RUM) and bitter vetch (CV. local Kerseneh) were used.

Herbage was determined by harvesting 1.5 x 5m^2. To determine botanical composition, plants in two 0.5 x 0.5m^2 quadrates per plot were sickle-harvested, hand-separated and sub samples of each species dried 42 h at 100°C for dry matter determinations. Relative yields of both crops were calculated as the ratio of yields

Table 1: Weight of barley seed (kg ha^{-1}) used for the combinations of bitter vetch: barley sowing ratios and vetch sowing rates (calculated as seed number)

Vetch: Barley sowing ratio	Bitter vetch sowing rates (kg ha^{-1}) 80	100	120	140
100: 0	Nil	Nil	Nil	Nil
85: 15	02.14	03.52	04.91	06.28
70: 30	06.19	09.29	12.39	15.49
65: 45	10.86	16.17	41.49	26.80
40: 60	17.66	25.92	34.19	42.45

in mixture to sole cropping. Relative yields total (the sum of both relative yields) was used as the criterion for mixed stand advantage as both vetch and barley were desired crops as indicated by Caballero *et al.* (1995). The value of unity is the critical value with the intercrop favored above and the pure stands favored below that value (Vandermeer, 1990). Yield response of vetch affected by the density of barley was calculated as the difference in yield between mixtures and pure stand. The proportion of the vetch in the total yield was thus related to the densities of the two crops.

Forage quality measured as Neutral detergent fiber (Goering and Van Soest, 1970) and crude protein was determined by Kjeldahl standard procedures, on sub-samples of both crops oven-dried for 24 h at 70 ^{0}C. The data were subjected to analysis of variance (mean effects and interaction), where effects were significant ($P \leq 0.05$) and the least significant difference (LSD) was calculated to determine which means differed, using the MSTAT-C computer program (Michigan State University).

Results and Discussion

Increasing the sowing rate of vetch did not significantly affect the herbage production of mixed cropping. Overall dry matter yields were 1210, 1243, 1218 and 1400 kg ha^{-1} at vetch densities of 80, 100, 120 and 140 kg ha^{-1}, respectively. There was no significant vetch sowing rates X sowing ratio interaction for composition, because the vetch contribution decreased at all vetch sowing rates as barley-sowing proportion increased (Table 2). From the 85:15 to the 40: 60 vetch: barley sowing ratios, mean vetch contribution to forage yield dropped by 45%, relative yield of vetch dropped by 53%, and relative yield barley increased by 200 % (Table 3). Sole cropping of barley differed significantly from that of vetch in herbage production and both sole cropping have significantly different mean total yields from the mixed cropping. Averaged together, the mixed cropping out-yielded the sole cropping of vetch by 96%, but were out-yielded by the sole cropping of barley by 63%.

As barley sowing proportions increased, the relative yield of vetch decreased and that of barley increased. Relative yield total of the mixed cropping exhibited a decreasing trend as barley proportion increased. For mixed cropping, with 15 % barley, relative yield total exceed unity, suggestions a mixed stand advantage at lower seedling proportion of barley. This trend suggested potential for higher relative yield total with even lower proportions of barley. Sole cropping production showed no significant advantage over the mixed cropping (Table 3). This is often attributed to the fact that different crops can complement each other and make better total use of resources when growing together rather than separately (Reddy and Willey, 1981).

Differences between yields of vetch grown in the mixed cropping and pure stand vs. the sowing density of barley appear in Table 4. A significant sowing rate X sowing ratio interaction occurred because the switching effect was not the same at different sowing rates. At 15% barley, the 80 and 100 vetch sowing rates were positive, at 30% barley the 140 vetch-sowing rate was positive, and the 120 and 140 vetch sowing rates were negative. At 45 and 60% barley, competition was present at any vetch-sowing rate. Two theoretical principles for understanding mechanisms for yield advantages in mixed cropping have been proposed by Vandermeer (1989). These are derived from well-known concepts in ecology that have been used to explain the structure of natural plant communities. The first is the "Competitive Production Principle", which states that a mixed crop may be successful if the resource requirements of the two species are sufficiently different. Less competition for the resources of light, water, or nutrients may occurs in a mixed crop than occurs in sole crop, which may lead to yield advantages. This principle of niche differentiation may be operative in the dimensions of either time or space (Putnam and Allan, 1992). The second principle has been termed the "Facilitative Production Principle". This occurs when one species benefits directly from modification of the environment by the other species in the mixture. Plants, which grow close to each other, basic physiological principles suggest that they will compete for environmental resources regardless of facilitation. If competition and facilitation are both operatives, the net effect could switch from positive to negative as a function of density (Vandermeer, 1990).

The results suggested that the net response of bitter vetch to an increasing population density of barley had a threshold pattern with no facilitation at the lower sowing proportion of barley (15%), and an increasing level of competitive depression at barley sowing proportions over 30% in the mixed cropping. The yields of mixed cropping were intermediate between the higher and the lower yielding sole cropping species, which agrees with Vandermeer (1984). Results of the present study are in accord

Table 2: Bitter vetch proportion of dry matter as affected by sowing proportion of barely and sowing rates of bitter vetch

% Barley seed in mixed cropping	Bitter vetch sowing rate (kg ha^{-1}) 80	100	120	140
0	1.00	1.00	1.00	1.00
15	0.72	0.74	0.80	0.78
30	0.68	0.70	0.62	0.75
45	0.57	0.59	0.54	0.50
60	0.44	0.35	0.49	0.40

LSD value = 0.052

Table 3: Forage production and quality parameters and relation yield of pure stand and mixed cropping of bitter vetch and barley from four sowing ratio

			Relative yield			Fiber and protein content (g kg^{-1})	
Vetch: Barley ratio*	DM yield (kg ha^{-1})	Vetch contribution (%)	Barley	Vetch	Total	Cp	NDF
Pure stand vetch	1120	100.0	1.00	-	1.0	202.3	374.2
85 : 15	2250	64.58	0.89	0.09	0.98	180.7	398.4
75 : 30	2220	57.08	0.78	0.11	0.89	145.3	422.7
65 : 45	1990	43.26	0.55	0.19	0.74	117.5	472.1
40 : 60	2330	29.16	0.42	0.27	0.69	095.2	513.6
Pure stand barley	3570	00.0	-	1.0	1.0	071.4	548.3
LSD ($P \leq 0.05$)	224	02.36	0.03	0.07	0.05	009.21	022.7

* All values are means of years and four sowing rates of vetch CP, Crude Protein NDF, Neutral Detergent Fiber

Table 4: Herbage yield (dry matter) differential of bitter vetch at varying sowing rates and increasing sowing proportion of barley

Barley % seed in mixed cropping	Vetch sowing rate (kg ha^{-1}) 80	100	120	140
0	0.00	0.00	0.00	0.00
15	+0.14	+0.75	-0.80	-0.20
30	-0.25	-0.50	-0.25	+0.10
45	-0.12	-0.12	-0.14	-0.94
60	-0.11	-0.17	-0.12	-0.15

Values with " -" indicated that it is in the competition while values with " + " indicated the facilitation

with those of Caballero *et al.* (1995) that indicated that Dry matter yields of mixtures were not affected by sowing ratio or sowing rate of vetch.

Forage yields were not affected by vetch sowing rates within the range of 80 to 140 kg ha^{-1}. Adequate contribution of vetch to forage yield is incompatible with high DM yield of barley. Yield of mixed cropping did not increase, however, within the range of 15 to 60 % barley proportions.

Crude protein concentration in mixed cropping increased with increasing vetch proportions, while NDF content decreased (Table 3). The increase in crude protein content was associated with the increase in vetch in the mixed cropping. Quality components indicated an advantage for vetch as compared to barley. Improving small grain quality by mixed cropping with vetch has been reported by Jimenez *et al.* (1989). The difference between vetch and barley may affect total ingestion of protein due to the negative relationship existing in NDF content and dry matter intake by ruminants (Rohweder *et al.*, 1978). The results of this study suggested that adequate vetch contribution and forage quality can be obtained only at low barley sowing proportions (15 or 30%). At barley sowing proportions above 30%, vetch contributions to forage yield fell below 50%, a value recommended as a minimum for quality hay (Caballero, 1986). Ultimately, the net effect of barley in the mixed cropping was to increasing competition as barley density increased. The data suggest the possibility of greatest vetch yield with barley proportions below 15%.

If high herbage yield is the objective, the barley sole crop will be selected. Crude protein content regardless of herbage yield should not be a criterion to define the best sowing rate of barley-vetch mixture. High forage quality of the mixed cropping would require a very low sowing proportion of barley to increase vetch contribution to forage yield.

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