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# ON-FARM TRIALS WITH FORAGE LEGUME–BARLEY COMPARED WITH FALLOW–BARLEY ROTATIONS AND CONTINUOUS BARLEY IN NORTH-WEST SYRIA

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SUMMARY

Over a period of seven years farmers participated in trials in which common vetch (*Vicia sativa* (V)) or chickling (*Lathyrus sativus* (C)) replaced the fallow in a barley (*Hordeum vulgare*)–fallow rotation (F) or were introduced into continuous barley cropping (B) – giving a total of four rotations, B–F, B–B, B–V and B–C. Trials on 4 ha, 2 ha per phase of each rotation, were replicated on 6–8 farms. Some vetch and chickling crops were grazed in spring. Mean seven-year dry matter yields were 2.91 t $ha^{-1}$ for B–F, 4.82 t for B–B, 5.02 t for B–C and 5.32 t for B–V; total crude protein outputs were twice as high from rotations including legumes; and the B–V rotation yielded most metabolizable energy. Realizing the benefit, farmers started to adopt vetch. In 1991 three farmers were growing vetch on 7 ha but by 1997 174 farmers in 15 villages were growing vetch on 420 ha. Forage legumes will not, however, become more widely grown until inexpensive and efficient mechanized methods of harvesting the mature crop are available in order to avoid the high cost of hand labour. Drought and cold tolerance, early maturation and high harvest index may also enhance farmers' interest in forage legumes.

## INTRODUCTION

Pressure on agricultural land is forcing farmers in north-west Syria to use non-sustainable cultural practices such as cereal monoculture (Jones & Singh, 1995). In just ten years, the fallow area in El Bab district decreased from more than 40% (Tully, 1984) to about 10% (Pape-Christiansen, 1997). This intensification has generated serious problems associated with declining soil fertility and inadequate feed supply for livestock. Furthermore barley monocropping encourages a seed gall nematode (*Anguina tritici*) locally called Abu Ulaiwi, and this devastates barley yields (Bahhady *et al*., 1997).

To help overcome these problems, efforts have been made to introduce forage legumes (Tully *et al*., 1985), in rotation with cereals in order to supply nutritious feed to the expanding population of small ruminants. On-station research continues to show how such crops increase the quality and quantity of feed

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(Jones, 1990; Abd El-Moneim, 1993). To confirm the information flowing from such studies and to get farmers to adopt these crops, on-farm testing of forage legumes became an essential step.

This paper highlights results of a project aimed at introducing forage legumes into rotations in the El Bab district of north-west Syria.

## MATERIALS AND METHODS

### *Project site and climate*

The project started in October 1986 near El Bab, in Aleppo Province in north-west Syria, and ran through the 1992–93 season. Trials were replicated on six to eight farms. The soils are mostly cracking clays (Terra Rosa); many plots had shallow (<20 cm) soils, although some had medium (20–40 cm) and deep (>40 cm) soils. A rain gauge was installed at one farm. Rainfall was below average (266 mm) in four of the seven years (Table 1).

The first year was close to average; the second year had record high rainfall. The third year was very poor in both rainfall quantity and distribution. The fourth and fifth seasons were again below or about average but distribution was better. The sixth year had 36 mm of ineffective rainfall late in the season, which should not be considered useful to the barley. The final year was marked by erratic opening rainfall and a low total for the season.

### *Treatments*

(1) Trials compared fallow (F) or barley (B) with common vetch (V) (*Vicia sativa*) or chickling (C) (*Lathyrus sativus*) each in rotation with barley. The rotations were therefore barley–fallow (B–F), barley–barley (B–B), barley–vetch (B–V), and barley–chickling (B–C).

(2) Ammonium nitrate (30–60 kg N $ha^{-1}$) was hand-broadcast on half of the barley crop. Nitrogen and rotation were 'stripped' across each other within each phase and each farm.

Table 1. Monthly rainfall (mm) data from El Bab, north-west Syria during the course of the project, 1986–1993.

| Month | 1986–87 | 1987–88 | 1988–89 | 1989–90 | 1990–91 | 1991–92 | 1992–93 | Mean |
|---|---|---|---|---|---|---|---|---|
| October | 2 | 63 | 55 | 5 | 2 | 22 | 0 | 21 |
| November | 39 | 53 | 50 | 38 | 50 | 27 | 53 | 44 |
| December | 44 | 57 | 56 | 43 | 16 | 70 | 0 | 41 |
| January | 84 | 68 | 0 | 39 | 46 | 20 | 39 | 42 |
| February | 20 | 63 | 0 | 56 | 29 | 65 | 47 | 40 |
| March | 67 | 83 | 40 | 22 | 66 | 0 | 43 | 46 |
| April | 6 | 78 | 0 | 4 | 49 | 0 | 16 | 22 |
| May | 0 | 0 | 0 | 0 | 17 | 36 | 16 | 10 |
| Total | 262 | 465 | 201 | 207 | 275 | 240 | 214 | 266 |

On each of the six to eight farms, the rotations were established on about 4 ha, half sown to feed legumes, continuous barley or left fallow, and half sown to barley each year.

### *Land preparation, sowing, fertilization and harvesting*

Ducksfoot cultivators on tractors belonging to the farmers or hired, together with farm labour, were used to prepare the land and sow the crops. The ducksfoot cultivators are light implements which have a non-inverting action and till to a depth of 15–20 cm. The local landrace of barley, Arabi Abiad, was sown at 120 kg seed $ha^{-1}$. If farmers wanted lambs to graze the forages, they sowed uninoculated forage legume seed at 160 kg $ha^{-1}$, but if they wanted the forages for seed and straw, they sowed 140 kg seed $ha^{-1}$, the latter option was preferred on deeper soils. Local landraces of vetch and chickling were used, and the seed was drilled in October–November.

All fertilizer was applied in the barley phase. Triple superphosphate was hand-broadcast depending on the phosphorus (P) status of the soils; soils with more than 15 ppm Olsen available-P were not fertilized; soils with 6–10 ppm were given 14.4 kg P $ha^{-1}$ and soils with less than 6 ppm were given 28.8 kg P $ha^{-1}$. Ammonium nitrate was hand-broadcast on half of the barley crop in late winter (January or February) at a nitrogen (N) rate of 30–60 kg $ha^{-1}$ depending on soil N status.

Forage legumes harvested for seed and straw were hand-pulled when close to physiological maturity, left in small piles to dry, transported, and mechanically threshed using farm labour.

### *Measurements and procedures*

*Herbage, grain and straw yields*. Dry matter (DM) yields for hay, seed and straw were all estimated using five 1-$m^2$ samples per plot, cut or hand-pulled at ground level, and dried at 60 °C. For plots that were grazed, yields were estimated before and after grazing from inside cages measuring 1.8 × 1.8 m. Dry matter yields were converted into yields of metabolizable energy (ME) and crude protein (CP) using concentrations of ME and CP previously established at ICARDA.

*Grazing management*. On farms that chose the grazing option, vetch and chickling plots were grazed by a single group of lambs. Forage was fenced and grazing started between mid-March and early April, depending on the season. Stocking rates were between 20 and 30 lambs per ha and a daily supplement of 300 g barley grain per lamb was offered.

*Soil samples*. Soils were sampled in October each year to a depth of 20 cm in all treatments and analysed for organic matter, Olsen-P, and Kjeldahl-N. The data obtained were used to guide the fertilizer recommendations for the following season.

*Interviews and economic analysis*. Farmers were interviewed during the cropping season to record costs of all field operations and to obtain their opinions about the forage legumes. Total sales revenue from lambs, grain and straw, and direct costs, including seed, fertilizer, cultivation, labour and harvesting costs were recorded.

*Experimental design and statistical analyses*. Each farm included all rotations with both a cereal and non-cereal phase of the rotation in each year, but the two phases were not necessarily adjacent. Within the barley phase of each rotation, the plot was divided into two subplots to which the two levels of nitrogen (0 and 30–60 kg N $ha^{-1}$) were randomly assigned. Farms were considered a blocking factor. Analyses of variance were used to evaluate error terms (comprising between and within plot errors) and the effects of rotation, N, rotation × N and the interaction of the above with time components, generally following the methods described by Yates (1954) and Cady and Mason (1964).

## RESULTS

*Barley yields*

Grain and straw yields of barley were influenced by nitrogen and rotation, but there was no rotation × nitrogen interaction. The N effect on barley yields differed between years, but much of the variation could be attributed to rainfall (Tables 1 and 2). Average grain yields increased by about 10% with applied N, although in three of the seven years there was no increase. The straw response was more pronounced, with a range of increase from 9% to 36%, the biggest improvement occurring in wetter years. Overall, N increased total barley yield by an average of 0.54 t $ha^{-1}$ (Table 2).

Grain and straw yields were greater for B–F than for B–B rotations except in 1986–87, but this was the first year of the trial and the preceding crop had been barley for all treatments. Averaged over all years, B–F provided 18.5% higher barley grain yields and 16.4% higher straw yields than B–B.

*Forage legume yields*

Over the entire series of years grain yields of vetch and chickling were not statistically different, but straw yields were dissimilar, with 0.5 t $ha^{-1}$ greater production from vetch (Table 3).

*Dry matter (DM), crude protein (CP) and metabolizable energy (ME)*

Total DM, CP and ME yields were affected by rotation treatment and N application (Table 4). These factors did not interact with each other, but interacted with time.

Feed production was greatest from the B–V and B–C rotations. Mean DM yields for seven years, summed for both phases of each rotation were 2.91 t $ha^{-1}$ for B–F, 4.82 t for B–B, 5.02 t for B–C and 5.32 t for B–V. Total outputs of crude protein from the rotations including legumes were double the average from B–F

Table 2. Mean dry matter (DM) yields for barley grain and straw harvested from barley–vetch (B–V), barley–chickling (B–C), barley–barley (B–B) and barley–fallow (B–F) rotations between 1986–87 and 1992–93.

| | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1986–87† | 1987–88 | 1988–89 | 1989–90 | 1990–91 | 1991–92 | 1992–93 | Mean |
| Rotation | | | | *Grain (t DM ha$^{-1}$)* | | | | |
| B–V | 0.83 | 1.46 | 1.04 | 0.92 | 1.39 | 1.13 | 1.54 | 1.19 |
| B–C | 1.11 | 1.64 | 1.06 | 0.86 | 1.45 | 1.11 | 1.53 | 1.25 |
| B–F | 0.95 | 1.38 | 1.20 | 1.13 | 1.48 | 0.99 | 0.74 | 1.12 |
| B–B | 1.01 | 1.30 | 0.74 | 0.74 | 1.20 | 0.85 | 0.60 | 0.92 |
| s.e. | | | | 0.079 | | | | 0.041 |
| Nitrogen‡ | | | | | | | | |
| −N | 0.80 | 1.34 | 0.99 | 0.85 | 1.35 | 1.01 | 1.04 | 1.05 |
| +N | 1.15 | 1.55 | 1.03 | 0.97 | 1.40 | 1.03 | 1.17 | 1.19 |
| s.e. | | | | 0.048 | | | | 0.012 |
| Rotation | | | | *Straw (t DM ha$^{-1}$)* | | | | |
| B–V | 2.20 | 2.68 | 1.93 | 1.60 | 1.85 | 1.16 | 1.52 | 1.85 |
| B–C | 2.57 | 2.95 | 2.06 | 1.56 | 1.54 | 1.17 | 1.58 | 1.92 |
| B–F | 2.28 | 2.47 | 1.88 | 2.07 | 1.95 | 1.07 | 0.66 | 1.77 |
| B–B | 2.40 | 1.96 | 1.46 | 1.35 | 1.78 | 0.84 | 0.56 | 1.48 |
| s.e. | | | | 0.14 | | | | 0.066 |
| Nitrogen | | | | | | | | |
| −N | 1.84 | 2.25 | 1.71 | 1.42 | 1.65 | 1.01 | 0.98 | 1.55 |
| +N | 2.89 | 2.78 | 1.95 | 1.87 | 1.91 | 1.11 | 1.18 | 1.96 |
| s.e. | | | | 0.089 | | | | 0.025 |

† In 1985–86 the previous crop was barley; ‡ −N = no nitrogen, +N = mean of applied N rates.

and B–B treatments. The B–V rotation gave the highest output of metabolizable energy. There was no N × rotation interaction; application of N increased barley DM yields by about 0.5 t ha$^{-1}$ for all rotations. Fertilizer N increased both DM and harvested CP by about 10% on average (Table 4), although there was no response in low rainfall years.

### *Lamb fattening using forage legumes*

For lambs grazing forage legumes liveweight gains averaged 186 g per lamb, and total gains averaged 194 kg ha$^{-1}$ (Table 5). Although the vetch and chickling were not grazed individually, farmers reported that lambs chose chickling before vetch.

## DISCUSSION

### *Barley–forage legumes versus barley–fallow or continuous barley*

For centuries, rainfed crop and livestock production in the region were integrated in an efficient and sustainable use of natural resources. Population

Table 3. Mean dry matter (DM) yields for legume grain, straw and hay harvested from barley–vetch (B–V) and barley–chickling (B–C) rotations between 1986–87 and 1992–93.

| | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rotation | 1986–87 | 1987–88 | 1988–89 | 1989–90 | 1990–91 | 1991–92 | 1992–93 | Mean |
| | | | | *Grain (t DM ha$^{-1}$)* | | | | |
| B–V | 0.69 | 0.86 | 0.18 | 0.24 | 0.39 | 0.28 | 0.44 | 0.44 |
| B–C | 0.59 | 1.10 | 0.37 | 0.20 | 0.47 | 0.28 | 0.48 | 0.50 |
| s.e. | | | | 0.061 | | | | 0.027 |
| | | | | *Straw (t DM ha$^{-1}$)* | | | | |
| B–V | 1.98 | 3.44 | 1.05 | 1.42 | 3.09 | 0.66 | 1.10 | 1.82 |
| B–C | 1.71 | 3.00 | 1.02 | 0.54 | 2.00 | 0.48 | 0.66 | 1.34 |
| s.e. | | | | 0.12 | | | | 0.047 |
| | | | | *Hay (t DM ha$^{-1}$)* | | | | |
| B–V | 1.09 | 3.75 | 0.84 | 0.89 | 0.78 | 0.75 | 0.82 | 1.27 |
| B–C | 0.89 | 3.16 | 0.77 | 0.51 | 0.47 | 0.44 | 0.49 | 0.96 |
| s.e. | | | | 0.101 | | | | 0.05 |

increase, however, has altered the existing equilibrium and has generated serious problems associated with declining soil fertility and inadequate feed supply for livestock (Jones and Singh, 1995). One of the most worrying regional problems is the widespread replacement of the barley–fallow system with continuous barley cultivation. In just ten years the fallow area decreased from more than 40% (Tully, 1984) to about 10% (Pape-Christiansen, 1997).

Our findings show that the introduction of forage legumes into rotations could provide a solution, by rebuilding soil fertility and providing nutritious feed. Averaged over the entire span of the experiment, barley following chickling and vetch produced more total DM yield than barley following fallow or continuous barley; total outputs of CP were also higher from rotations including legumes.

Annual barley yields in B–F rotations exceeded those in B–B rotations, but in the rotation with fallow there was only one barley harvest every two years, except in 1986–87; it should be noted, however, that in the first year of the trial the preceding crop was barley for all treatments. Averaged over all years, B–F provided 18.5% higher barley grain yields and 16.4% higher straw yields than B–B. Grain and straw yields of barley following fallow or barley were occasionally better than those from barley following forage legumes, but most of the time barley yielded better after legumes, particularly towards the end of the experiment, probably due to accumulation of soil N and organic matter from the legumes (White *et al.* 1994). In 1988–89, the grain yields after fallow were apparently stimulated by water storage in the soil profile, after a record rainfall in the previous year.

Grain yields of vetch and chickling were not statistically different, but vetch produced an average of 0.5 t ha$^{-1}$ more straw. This contrasted with results from

Table 4. Effect of rotations and nitrogen fertilizer on yields of air-dry matter (DM), metabolizable energy (ME) and crude protein (CP) of grain and straw from both phases of four crop rotations from 1987 to 1993.

| Year | Rotation | | | | Nitrogen fertilizer | |
|---|---|---|---|---|---|---|
| | B–V | B–C | B–B | B–F | −N | +N |
| | | | *(t DM ha$^{-1}$)* | | | |
| 1987 | 5.56 | 5.96 | 8.15 | 3.13 | 5.01 | 6.38 |
| 1988 | 8.63 | 8.69 | 4.81 | 4.03 | 6.18 | 6.90 |
| 1989 | 4.13 | 4.42 | 3.53 | 3.07 | 3.64 | 3.93 |
| 1990 | 4.25 | 3.23 | 3.90 | 3.21 | 3.35 | 3.94 |
| 1991 | 6.73 | 5.46 | 5.93 | 3.43 | 5.24 | 5.54 |
| 1992 | 3.26 | 3.02 | 3.30 | 2.00 | 2.83 | 2.96 |
| 1993 | 4.70 | 4.36 | 4.10 | 1.49 | 3.50 | 3.83 |
| s.e. | | 0.39 | | | 0.36 | |
| Mean | 5.32 | 5.02 | 4.82 | 2.91 | 4.25 | 4.78 |
| s.e. | | 0.096 | | | 0.068 | |
| | | | *(kg CP ha$^{-1}$)* | | | |
| 1987 | 217.3 | 223.3 | 211.6 | 80.2 | 166.8 | 199.4 |
| 1988 | 338.2 | 356.3 | 134.6 | 112.1 | 226.0 | 244.6 |
| 1989 | 137.8 | 160.2 | 99.9 | 89.3 | 118.5 | 125.2 |
| 1990 | 146.9 | 112.3 | 108.6 | 90.2 | 107.4 | 121.6 |
| 1991 | 243.8 | 218.2 | 179.6 | 104.8 | 183.5 | 189.8 |
| 1992 | 135.4 | 126.1 | 113.9 | 64.0 | 108.3 | 111.4 |
| 1993 | 197.6 | 186.4 | 127.6 | 50.7 | 135.4 | 145.7 |
| s.e. | | 13.1 | | | 11.8 | |
| Mean | 202.4 | 197.5 | 139.4 | 84.5 | 149.4 | 162.5 |
| s.e. | | 4.09 | | | 2.89 | |
| | | | *(GJ ME ha$^{-1}$)* | | | |
| 1987 | 21.39 | 23.41 | 31.51 | 12.00 | 19.55 | 24.61 |
| 1988 | 33.76 | 35.01 | 19.47 | 16.17 | 24.72 | 27.49 |
| 1989 | 16.15 | 17.65 | 14.17 | 12.61 | 14.61 | 15.68 |
| 1990 | 16.50 | 13.03 | 15.66 | 12.92 | 13.43 | 15.63 |
| 1991 | 26.24 | 22.72 | 25.04 | 14.56 | 21.62 | 22.67 |
| 1992 | 14.15 | 13.27 | 14.83 | 8.81 | 12.53 | 13.00 |
| 1993 | 20.36 | 19.29 | 16.83 | 6.74 | 15.10 | 16.51 |
| s.e. | | 1.52 | | | 1.39 | |
| Mean | 21.22 | 20.63 | 19.65 | 11.97 | 17.36 | 19.37 |
| s.e. | | 0.425 | | | 0.300 | |

Table 5. Performance of lambs grazing forage legumes between 1986–87 and 1992–93. Data are averages of five farms, all with shallow soils (<20 cm).

| | 1986–87 | 1987–88 | 1988–89 | 1989–90 | 1990–91 | 1991–92 | 1992–93 | Mean |
|---|---|---|---|---|---|---|---|---|
| Grazing days | 33 | 48 | 24 | 31 | 40 | 21 | 32 | 33 |
| Number of lambs ha$^{-1}$ | 30 | 39 | 29 | 36 | 37 | 25 | 36 | 33 |
| Daily gain (g lamb$^{-1}$) | 210 | 172 | 139 | 186 | 177 | 217 | 204 | 186 |
| Liveweight (kg ha$^{-1}$) | 200 | 324 | 104 | 208 | 209 | 107 | 205 | 194 |

Breda, an experimental site at which rainfall is similar but soils are much deeper than at El Bab. Here Thomson *et al.* (1992) found that vetch and chickling produced similar amounts of straw. Seven-year results obtained in the present project suggested that B–V is the more productive rotation biologically; annual DM production was 0.3 t $ha^{-1}$ more than that from the B–C rotation.

*Adoption of vetch by farmers*

The big production differences between continuous barley and the other systems, and the frequent insect infestation of continuous barley fields together convinced those El Bab farmers involved in on-farm research of the value of a rotation system. Farmers expressed their eagerness to introduce the B–V rotation. Whereas in 1991 only three farmers in three villages were growing about 7 ha vetch, the number had increased in 1997 to 174 farmers in 15 villages, with a total vetch area of about 420 ha (Table 6). Even more significant were the benefits that farmers saw in their barley when vetch crops interrupted the cycle of gall nematode that has become quite widespread in recent years and which devastates barley grain yields.

Some farmers believe that the grazing option makes better sense than growing legumes for seed and straw, especially on shallow soil. There are several reasons for this opinion: (1) grazing eliminates the need for weeding and this is important in the El Bab area where no selective herbicides are available for the elimination of broadleaved weeds in forage legumes; (2) grazing is less expensive than hand-harvesting; and (3) grazing the legumes prior to normal maturity shortens the crop's exposure to weather risk.

Other farmers chose to harvest seed and straw at maturity. These farmers maintained that forage legumes would not be grown widely until inexpensive and efficient mechanized methods of harvesting are available to avoid the high cost of hand labour. Some promising methods do exist. Farmers who wish to save the maximum amount of straw for feed can cut with a sicklebar mower at physiological maturity to avoid leaf drop and pod shattering, after which the crop can be gathered from the windrows for threshing at a convenient location. However, even mechanized harvesting will face problems: in dry years plants are short, resulting in poor recovery of straw; in wet years the plants tend to lodge, which slows down

Table 6. Increase in the number of villages and farmers and the total area growing vetch in the El Bab District of Aleppo Province.

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| Villages | 3 | 4 | 3 | 5 | 9 | 11 | 15 |
| Farmers | 3 | 5 | 8 | 17 | 26 | 50 | 174 |
| Hectares | 7.5 | 17 | 21 | 34.7 | 52 | 109 | 421 |

the cutting process. Nevertheless, farmers prefer this method to hand-harvesting, because labour costs are becoming prohibitive.

## CONCLUSIONS

A continued intensification of Syrian rainfed cropping systems appears inevitable, as pressure on the available land increases. However, studies with participating farmers have shown that annual forage legumes, in particular common vetch, can form an acceptable component of their barley-based crop sequences. Such crops not only stimulate greater rotational productivity of DM and, especially, CP, for animal feed, but also confer a degree of biological protection against pests that otherwise tend to build up in land cropped every year to barley. However, before these more sustainable barley–forage legume systems can be adopted widely, a sustainable methodology for vetch seed production must be established and mechanical harvesting encouraged. Research is continuing to develop non-shattering forage legumes with drought and cold tolerance, early maturation and higher harvest indices, which will increase their value and attractiveness to farmers.

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