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Yields in vetch-wheat mixed crops and sole crops of wheat

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Abstract. Field trials with common vetch (*Vicia sativa* L.) and spring wheat (*Triticum aestivum* L.) mixes were conducted from 1994 to 2004 on pseudopodzolic moderately moist soils in the trial fields of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences at Eerika, outside Tartu (58º 23´ N, 26º 44´ E). The results of the research showed that in cases where the yields of post-cereal wheat monocultures were 1500–3000 kg ha^{-1} vetch-wheat mixed crops (at the seed densities of 50 germinating vetch seeds and 250 germinating wheat seeds per m^2) guaranteed an approximate harvest of 3000 kg ha^{-1}, even under no nitrogen fertilisation, provided the total amount of precipitation in the growth period was 300 ± 50 mm. If the yields of monocultural wheat topped the level of 3000 kg ha^{-1}, mixed crops, however, lost their advantage over wheat monocultures as the latter's grain harvests were greater in those cases. Vetch-wheat mixed crops maintained their advantage over sole crops of wheat insofar as protein yields were concerned, primarily due to the high protein content of vetch. The extra gain in the protein yields of mixed crops compared to wheat monocultures was 100–500 kg ha^{-1} in our study, and was heavily dependent on the protein levels monocultural wheat was able to produce in each particular case.

Key words: mixed crops, common vetch, wheat, yield, protein yield

INTRODUCTION

The inclusion of common vetch in a crop rotation is considered a precondition to increasing the overall production of the crop rotation (Yau et al., 2003). Under suitable circumstances, vetch is capable, with the help of *Rhizobaceae*, of fixing atmospheric nitrogen (Mueller & Thorup-Kristensen, 2001). Half of the amount of the nitrogen fixed will satisfy the nitrogenous requirement of vetch itself and the other half will be left over for succeeding crops. The growing of vetch in a monoculture is questionable as its plants are susceptible to lodging. Furthermore, weeds reduce the seed yield of monocultural vetch by up to 71% (Dimitrova, 1997). Accordingly, spring vetch should be grown in a mix with support crops. Of cereals, wheat, oats and triticale would make a suitable support culture for vetch (Sobkowicz & Śniadu, 2000; Ceglarek et al., 2004). Support crops shorten the growth period of vetch, promote more even ripening of vetch seeds and reduce the extent of lodging of the legume crop.

The advantage of growing vetch and wheat together is that vetch has a well-developed taproot system while wheat has a hair root system. Therefore, they do not compete with each other for nutrients available in the soil. Vetch-wheat mixes have also been reported to produce higher seed and protein yields than cereal monocultures (Jensen, 1996), even under circumstances where they succeed a cereal crop and no use is made of mineral nitrogen fertilisers (Lauk et al., 1999). Thus, the growing of mixed crops would first and foremost be suitable for ecological methods of farming, simultaneously serving, to a certain extent, as a substitute for mineral nitrogen fertilisers.

During the period of study, we obtained fairly controversial results for the yields of vetch-wheat mixed crops. Therefore, the objective of this paper was to establish the conditions in which intercrops of vetch and wheat produce greater seed harvests than wheat in pure stands, and the efficiency of vetch-wheat mixes as regards protein yield. We also tried in our study to identify the correlation between the total precipitation in the growth period and the seed yield of the vetch-wheat mix.

MATERIALS AND METHODS

Field trials with spring vetch-spring wheat mixed crops were conducted from 1994 to 2004 on pseudopodzolic moderately moist soils in the trial fields of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences at Eerika, outside Tartu. Properties of the soil: pH_{KCl} 5.8 to 6.2, content of organic matter 2.8 to 3.2%, content of elements in A horizon: available (AL method) P 145 to 174 mg kg^{-1} and K 150 to 180 mg kg^{-1}. Phosphor and potassium fertilisers were not used in the trials, since the experimental soils' need for P and K was small. In all years, the preceding crop was spring wheat fertilised with N_{60}.

The efficiency of the mixes was investigated by analysing the field trials, in which common vetch (variety 'Carolina') was grown in combination with different spring wheat varieties ('Tjalve', 'Meri' or 'Helle'), both under no nitrogen fertilisation and on soils fertilised with nitrogen (N_{34}, N_{50} or N_{68}). Therefore, the data for 1995, 1996 and 1998, when the mixes were preceded by other crops not meeting the requirements, were excluded from the analysis. The data for 1999 and 2002, when the vegetation period was extremely dry and with relatively high air temperatures, were excluded from the investigation of mixed crop efficiency as these years were extremely unfavourable for vetch growth. However, the data for these years were used in determining the correlation between the amount of precipitations and mixed crop seed yields. Only data from soils without nitrogen fertiliser were used in the determination of the correlation.

Information about the weather was obtained from the Eerika Meteorolocical Station near Tartu. Protein content was determined in the Laboratory of Plant Biochemistry of the Estonian University of Life Sciences by using Kjeltec's apparatus and Tecotar AN assessment methods (Nx6.25). The yields of crude protein were calculated on the basis of desiccated yield and crude protein content in the dry components. The yields were calculated at 14% water content.

Vetch-wheat mixed crop efficiency was investigated using, on the one hand, monocultural wheat variants and, on the other hand, vetch-wheat mixed crop variants, in which the densities of the components in the seed mix were 50 germinating vetch seeds per square metre and 250 germinating wheat seeds per square metre, respectively. The difference between the yields of the vetch-wheat mixes and the wheat monocultures were calculated, and the data were processed using linear regression analysis ($y = a + bx$). The values of x were wheat monoculture yields and those of y were the differences between the yields of vetch-wheat mixes and wheat monocultures.

The correlation between precipitation levels and vetch-wheat mixed crop yields was determined using the quadratic equation ($y = a + bx + cx^2$), in which the argument (x) was the amount of precipitation during the period of mixed crop growth and the argument function (y) was the vetch-wheat mixed crop yield in kilograms per hectare.

The reliability of the correlations in the trial series was evaluated using the control values of correlation coefficients (R) taken from corresponding tables based on the number of degrees of freedom (Little & Hills, 1972). In the article, use was also made of the following symbols:

R^2 – determination coefficient;
n – sample size; in regression analysis, number of pairs of comparison;
P – level of statistical significance.

RESULTS AND DISCUSSION

In the first years of our research (1994, 1997), vetch-wheat mixes yielded greater harvests than wheat monocultures (by 803–1100 kg per hectare) in cases where the preceding crop was a cereal and no fertilisers were applied (Lauk et al., 1999). Under fertilisation with nitrogen (N_{34}), however, differences in yield between mixed crops and wheat monocultures were much smaller (210–295 kg ha^{-1}). At subsequent stages of the research it appeared, however, that in four consecutive years (1999–2002) vetch-wheat mixed crop yields were smaller under no nitrogen fertilisation than wheat monoculture yields. Thus the findings did not corroborate our previous conclusions. We assumed that the reason were the relatively high yield levels of wheat or the low precipitation levels during the growth periods. The regression line and the regression equation in Fig. 1 demonstrate that our first premise was true.

The efficiency of post-cereal vetch-wheat mix, i.e. the issue of whether or not mixed crops produce higher yields than wheat monocultures, depends heavily on the yield level of monocultural wheat. If the amount of nitrogen available to wheat allows monocultural wheat to reach yield levels in the excess of 3000 kg ha^{-1}, vetch-wheat mixes lose their advantage and yield even smaller harvests than wheat monocultures. At monocultural wheat yield levels exceeding 3000 kg ha^{-1} there were only three occasions out of 14 when the yield levels of mixed crops slightly surpassed those of wheat monocultures. In 2000 and 2001, monocultural wheat produced relatively high grain yields (over 3000 kg ha^{-1}) even under no nitrogen fertilisation. As the result, most of the yields of vetch-wheat mixes were lower than those of wheat monocultures. Consequently, the nitrogen nutrition conditions in these years were relatively favourable to wheat on soils with no nitrogen fertilisation.

If monocultural wheat yield levels fell between 1500–3000 kg ha^{-1} then vetch-wheat mixes produced greater yields than wheat monocultures. The efficiency of vetch-wheat mixed crops was the greater the lower was the sole crop of wheat seed yields. In cases where monocultural wheat seed yields failed to reach the level of 3000 kg ha^{-1} vetch-wheat mixes produced a yield of approximately 3000 kilograms per hectare. It may be concluded from the figure (Fig. 1) that at monocultural wheat seed yield levels of 1500 kg ha^{-1} the efficiency of the mixed crops was slightly over 1500 kg ha^{-1} (i.e., exceeded the monocultural wheat yield levels by that amount).

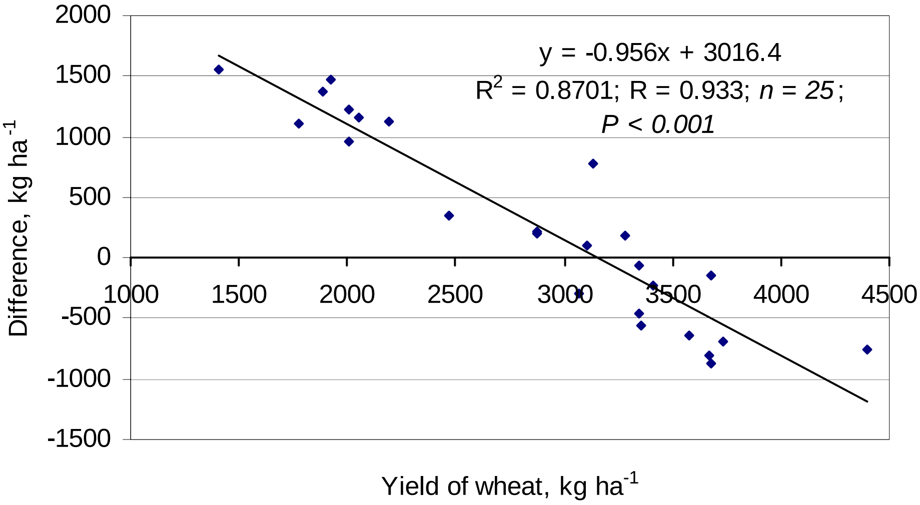

Fig. 1. Difference between the yields of vetch-wheat mixes and wheat monocultures.

At monocultural wheat seed yield levels of 2000 kg ha^{-1} the efficiency of the mixed crops was slightly over 1000 kg ha^{-1}. In general, a 1-kilogram change in wheat seed yield corresponds to a 0.96-kilogram change in vetch-wheat mixed crop efficiency. Consequently, vetch-wheat mixed crops are suitable under organic farming circumstances in which no mineral nitrogen fertilisers are used.

It must also be emphasised that this rule applies where both wheat monocultures and vetch-wheat mixed crops are preceded by a cereal crop. It does not apply where the crops under study are preceded by other crops (Lauk et al., 1999).

A second reason why mixed crop seed yields were lower than those of monocultural wheat were the precipitation levels during the growth period. Previous studies on the effect of weather conditions on the growth and development of the legume component in a mixed crop showed that in a droughty year legume generally produced a lower seed yield in a mixed crop while in a rainy year it produced a higher yield (Guilioni et al., 2003). At the same time, no studies have been performed on vetch sowing time in Estonia whereas in regions more to the south (Turkey) it is recommended that vetch be sown as early as possible since this is the only option for obtaining maximum seed or green biomass yields per hectare (Temel & Tan, 2002; Cakmakci et al., 2002).

It may be concluded from the correlation given in Fig. 2 that when preceded by a cereal crop vetch-wheat mixes produce yields of approximately 3000 kg per hectare provided the total precipitation in the growth period is 300 ± 50 mm. In the period under study the driest year was 1999, when the total precipitation in the mixed crop growth period was below 100 mm and the average air temperature was higher than the average. Therefore, vetch was early to complete its growth in mixed crops, and seeds in vetch pods ripened already by 24 July (the trial crops were sown on 24 April, wheat sprouted on 5 May and vetch on 7 May), i.e. 3–4 weeks earlier than usual. The wheat in the mixed crops ripened by 28 July, i.e. 4 days later than vetch. The mixed crop components were able to take up nutrients and synthesise organic matter in a considerably shorter period, notwithstanding the extreme weather conditions. The yields of the mixed crops fell below 1000 kg ha^{-1} (the lowest point in the correlation table).

The year 2002 was likewise characterised by dry weather (the total precipitation in growth period 150 mm) and relatively high air temperatures. As the result, the mixed crop yields remained below 2000 kg ha^{-1} (second lowest point in the correlation table). The vetch in the mixed crops ripened by 1 August (the trial crops were sown on 17 April), 3–4 days earlier than wheat. The correlation also incorporates, in essence, the higher-than-the-average air temperatures in the vegetation periods of the two above-mentioned years since the crops ripened and were harvested so early that the rainfall data for August could not be included. In other years, the total growth-period precipitation levels were higher because part of the August precipitation was also taken into account. In droughty years, vetch grown in a mix with wheat remained in the low-level. In the years with average air temperatures and precipitation levels, vetch came to maturity a few days later than wheat.

When preceded by a cereal crop, vetch-wheat mixed crops are fairly promising under organic farming, in which no use is made of industrial mineral fertilisers. Under conventional farming, in turn, vetch-wheat mixes help to save on mineral fertiliser purchase costs. In the first half of the research, post-cereal wheat monoculture yields under no nitrogen fertilisation were approximately 2000 kg ha^{-1} (Lauk et al., 1999).

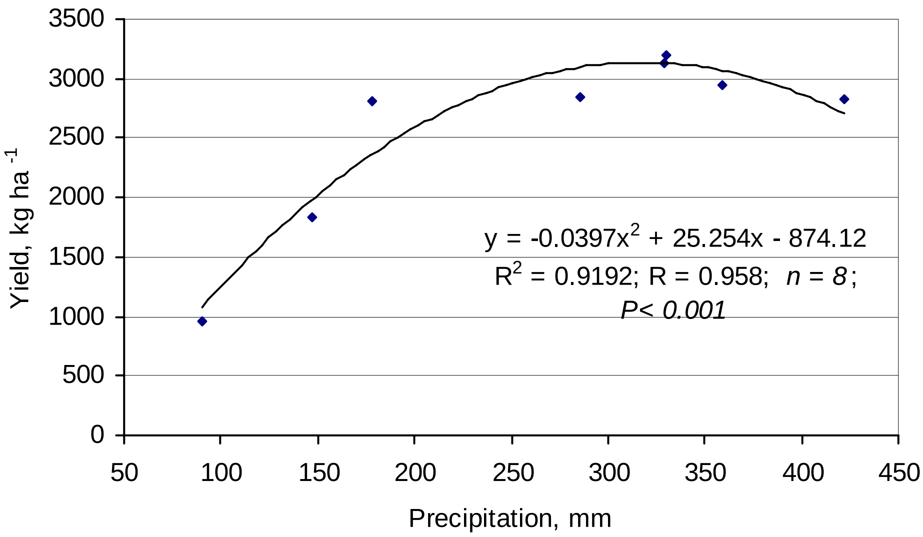

Fig. 2. Dependence of vetch-wheat mixed crop yields on precipitation levels in the growth period (from sowing to harvesting).

Accordingly, vetch-wheat mixes produce higher yields than wheat monocultures by about 1000 kg (see Fig. 1), except in droughty years. Based on the average efficiency of nitrogen fertilisation (N_{68}) in monocultural wheat (7.8 kg of grains per 1 kg of nitrogen), as evident from research (Lauk & Lauk, 2003), it may be maintained that the increasing of monocultural wheat yields by 1000 kg per hectare to reach the margin of 3000 kg ha^{-1} would require approximately 140 kg of nitrogen per hectare.

Vetch-wheat mixes are particularly efficient with regard to protein yield, primarily due to the high protein content of vetch (30.0–30.6 % in dry matter according to our data). It may be concluded from Fig. 3 that sole crop of wheat protein yields in the trials ranged between 175–480 kg ha^{-1} (Fig. 3). In cases where wheat yields and wheat protein yields remain low due to inadequate nitrogenous nutrition of wheat, post-cereal vetch-wheat mixes produce protein yields of 600–700 kilograms per hectare. The extra gains in protein yield obtained from mixed crops compared to wheat monocultures were 100–500 kg ha^{-1} in our study, and were heavily dependent on the protein levels monocultural wheat was able to produce in each particular case.

To make up for the difference, and in order for wheat monocultures to produce protein yields equal to or even greater than those of mixed crops, the protein yields of monocultural wheat must be approximately 550 kg ha^{-1}. This presupposes seed harvests exceeding 4500 kilograms per hectare. Such yield levels would require nitrogen fertilisers in fairly great quantities. In our study, the maximum level of nitrogen fertilisation was 68 kg of N per hectare. At such fertilisation rates, the three-year average protein yields of wheat monocultures were 480 kg ha^{-1} at the maximum (Lauk & Lauk, 2003). Consequently, where it may be assumed that the particular circumstances would not be conducive to sufficiently high cereal yields when the preceding crop is a cereal (N-fertilisers are little or not at all used), vetch-wheat mixed crops are suitable to be grown as fodder. They will produce fairly sufficient harvests and protein yields under the soil and weather conditions prevalent in Estonia.

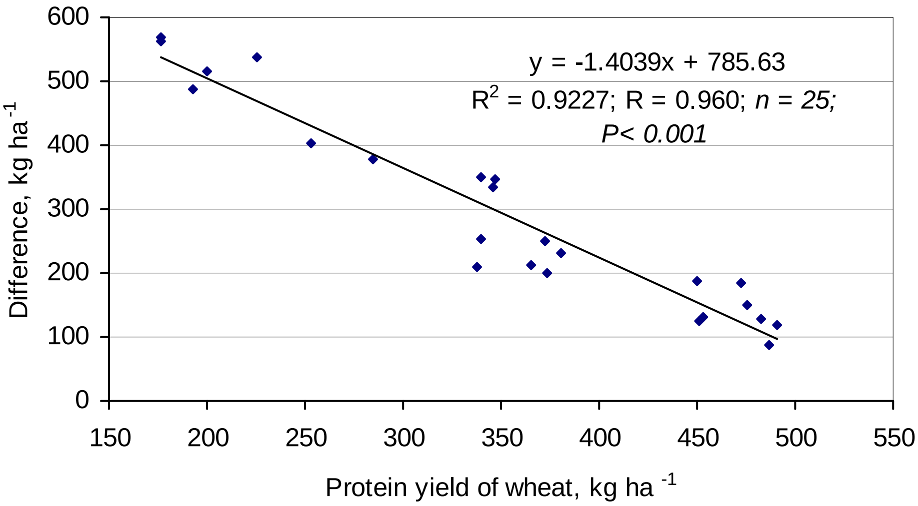

Fig. 3. Differences in protein yields between vetch-wheat mixed crops and wheat monocultures.

CONCLUSIONS

In cases where the yields of post-cereal wheat monocultures were 1500–3000 kg ha^{-1} vetch-wheat mixed crops (at the seed densities of 50 germinating vetch seeds and 250 germinating wheat seeds per m^2) guaranteed an approximate harvest of 3000 kg ha^{-1}, even under no nitrogen fertilisation, provided the total amount of precipitation in the growth period was 300±50 mm. If the yields of monocultural wheat topped the margin of 3000 kg per ha^{-1} mixed crops, however, lost their advantage over wheat monocultures.

Vetch-wheat mixes are particularly efficient with regard to protein yield, primarily due to the high protein content of vetch. In cases where wheat yields and wheat protein yields remain low due to inadequate nitrogenous nutrition of wheat, post-cereal vetch-wheat mixes produce protein yields of 600–700 kilograms per hectare. The extra gains in protein yield obtained from mixed crops compared to wheat monocultures were 100–500 kg ha^{-1}.

When preceded by a cereal crop, vetch-wheat mixed crops are fairly promising under organic farming, in which no industrial mineral fertilisers are used. Under conventional farming, in turn, vetch-wheat mixes help to save on mineral fertiliser purchase costs.

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