WINTER WHEAT AND WINTER PEA INTERCROP: AN ALTERNATIVE TECHNOLOGY OF CROP MANAGEMENT PRESERVES HIGH YIELD QUALITY AND STABILITY AT LOW INPUT

Marianna VÁLYI-NAGY, Melinda TAR, Katalin IRMES, A.RÁCZ, I.KRISTÓ

Hungarian University of Agriculture and Life Sciences
Plant Production Scientific Institute
Alsó kikötő sor 9., 6726, Szeged, Hungary
*Corresponding author: **Valyi-Nagy.Marianna@uni-mate.hu***

Abstract. *In Hungary for the most part of the arable land were one-crop plant productions, which means mostly corn, wheat, barley, sunflower and autumn rape. This overproduction were increased the number of fodder need animals and protein requirement, which we couldn't be able to fulfill only from national production. Field pea (Pisum sativum subsp. arvense) has the highest yield of leguminous plants in the whole world. In spite of the continously growing demand of protein plant and excellent properties the sown area of field pea is very small in this region. Intercrop is a possible way to increase the sown area and diversificate plants to cultivating two or more simultaneously in the same field: sowing, nursing and harvest together. The research was established in one growing season (2019/2020), with 2 winter wheat species (GK Szilárd, Cellule) and one field pea species (Aviron), in 4 repeats, on 10 square meter random layout plots in the research station in Szeged-Öthalom. We use 2 different seed density in every species in every combination, and compared grain yield and inner content values of the mixed parcels with the control and fertilized plots. The grain yield of mixed wheat-pea stands is generally small, but in two cases we observed higher grain yield than the control plot, what we couldn't prove it statistically. In addition inner content values (crude protein, gluten, zeleny sedimentation value) were still the same level. There were no differences between wheat pure stands and plant associations statistically. The highest values without exception were winter wheat with fertilizer plots. However the most preferred plant association- because of their inner content- were the Aviron 100 seed m^{-2} with both winter wheat species.Our aim is to evolve an alternative technology for farmers how to produce by low input and high yield stability. Pea-wheat intercropping is a promising way to produce cereal grains in an efficient, economically sustainable and environmentally friendly way.*

Keywords: *winter wheat, winter pea, intercrop, yield stability, low input, sustainable production*

INTRODUCTION

The sowing structure was simplified in Hungary in the last 2 decades. Two-thirds part of the whole arable land were sown cereals (PEPÓ and SÁRVÁRI, 2011). One-crop farming is adventageous for machine park or partially from an agronomic point of view, but causes problems in crop rotation, plant protection and tillage at the same time (ANTAL, 2005a). Furthermore this grain sowing structure-just like other developping countiries- makes vulnerable our country. (PEPÓ and SÁRVÁRI, 2011). It is recommended to diversificate the current sowing structure gradually to increase the sown area of protein plants at first (GHALEY et al., 2005).

In the 1960s it was a powerful agricultural development in Hungary,when high yield potential cereal crops have tripled. This overproduction were increased the number of fodder need animals too. The sowing area of protein plants wasn't big enough to fulfill the protein requirements, today almost 15-20 % of protein is from national production (BOCZ, 1996).

In Western Europe, pea constitute an alternative to soybeans a protein –rich feedstock (BOURION et al., 2007). In Hungary sowing area of pea about 20-35 thousand hectares, with an average yield 1,5-2,3 t ha^{-1} (ANTAL, 2005b). It has a prominent role in livestock feeding because of its high protein content. Pea has an excellent preceding crop effect in national sowing structure, which increase yield stability and yield level (PEPÓ and SÁRVÁRI, 2011). Growing peas in pure stands is often considered difficult mainly as a result of its relatively low competitiveness against weeds (KRISTÓ et al., 2020a), poor resistance to lodging, high yield instability and sensitivity to fungal diseases (URBATZKA et al., 2011, GOLLNER et al., 2019). Intercropping is a widespread practise in low-input farming system especially in organic farming. In this association two or more crops sowing, nursing and harvest together in the same field during the growing season (CORRE-HELLOU et al., 2006). A yield advantage can be appear in legume and non-legume mixtures, when they are complement each other by the utilization of growth resources, which is more efficient than in sole crops (BEDOUSSAC&JUSTES, 2010, LITHOURGIDIS et al., 2011). Although both use soil inorganic nitrogen sources, the legume can also fix atmospheric N_2 in symbiosis with rhizobium. Mutual shading by crops, especially taller cereals- reduces biological N_2 fixation and yield of the associated legume. It can be improved by choosing a suitable plant type and structure (FUJITA et al., 1992). Intercropping can be improve advantegously stem strength and weed supression in winter peas (GRONLE et al., 2015), intercrops often reduce pest incidence thus allows lower inputs through reduced fertilizer-due to the nitrogen fixation in legumes- and pesticide requirements, minimizing environmental impacts of agricultue (LITHOURGIDIS et al., 2011, HAUGGAARD-NIELSEN et al., 2009). NEUGSCHWANDTNER&KAUL (2014) observed in intercrop with oat that nitrogen fertilization increased the competitive ability of oat, and total grain yields were generally lower in intercrops than in pure stands. This suggested that strong root structure of wheat makes suitable for supporting, but wheat suppress pea because of its nitrogen demand in the initial phase of development. NAUDIN et al. (2010) investigated the effect of nitrogen fertilizer in small proportion and timing, and observed that nitrogen acquisition dynamics and nitrogen sharing between cereals and peas were modified. Nitrogen fertilizer increased wheat growth, and decreased pea growth. Nitrogen fertilization delayed the decrease in the contribution of wheat to total biomass and maintained competitive ability over pea. Short-term inhibition of nitrates on symbiotic N_2 fixation was shown after nitrogen application. It was taking only few days, and took until pea flowering. N fertilization could be use as a tool to enhance the intercrop biomass by wheat, but may decreasing pea biomass and thereby reduce the fixed N_2. PELZER et al. (2016) noticed the relationship between number of seed and fertilization. They investigated the effect of fertilizer management on the performance of a winter pea-wheat intercrop. The fertilized 50:50 intercrop was a good compromise between yields, wheat protein concentration, nitrogen efficiency and limited residual soil nitrogen. The same proportion, but unfertilized plots had the lowest production. A early overfertilization increased the wheat yield, whereas a late overfertilization the wheat protein concentration. Increasing the proportion of pea produce more pea yield (KRISTÓ et al 2020b), higher proportion wheat with fertilization result in only wheat yield, but did not in grain protein concentration. LOCK&NOSTICZIUS (1992) emphasized that we have to be more careful with nitrogen fertilizers and control of its use with attention for the potential danger of pollution. Unnecessarily applied nitrogen fertilizers could be acidify soil, and lead to nitrate accumulation in ground water.We have to elaborate an environment friendly land use with low input and adaptive mineral fertilizer application to variable conditions. According to ABI-GHANEM et al. (2011) increasing the biological nitrogen fixation by legumes offer economic, environmental and agronomic profits which should be used in a greater extent as an alternative to synthetic fertilizers.

We assume that we can be able to increase not only the sown area of protein plant and preserve cultivable area of cereals but also decrease the rate of fertilizer application with maintance of inner contents and grain yield at high level. Our aim were to observe the development of winter wheat and pea in plant association, the effect of winter pea on grain yield and inner contents of winter wheat, define the optimal number of seeds and compare mixed parcels with the control and fertilized plots.

MATERIALS AND METHODS

Our investigations were made in one growing season (2019/2020), with 2 winter wheat species (GK Szilárd, Cellule) and one field pea species (Aviron), in 4 repeats, on 10 square meter random layout plots in the research station of Szeged-Öthalom. We used 2 different seed density in every species in every combination, and beside the mixed plots we set a control and a top fertilization plot. In the case of winter wheat considered 100% the 5 million seed ha^{-1} of the sowing density, and the 1 million seed $ha^{-1}$for winter pea. 60% sowing density of winter wheat was 3 million seed $ha^{-1}$and 600 thousand seeds of winter pea (table 1).

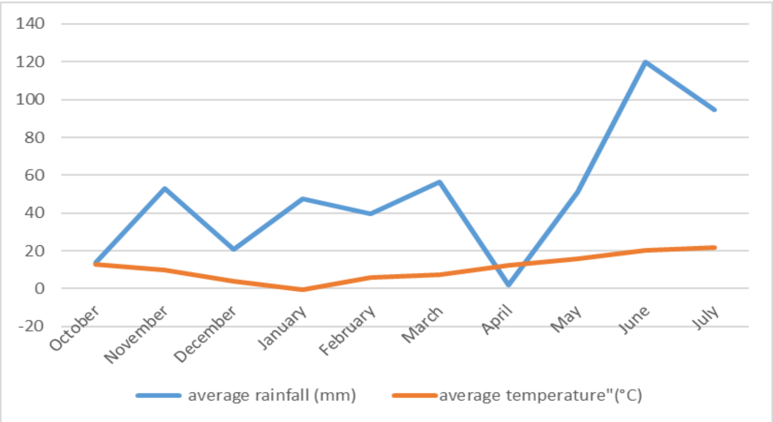
Table 1

Seed density in winter wheat- pea intercrop

		Number of seed of winter pea		
		0 seed m^{-2}	60 seed m^{-2}	100 seed m^{-2}
Number of seed of winter wheat	0 seed m^{-2}	-	0:60	0:100
	300 seed m^{-2}	60:0	60:60	60:100
	500 seed m^{-2}	100:0	100:60	100:100

GK Szilárd was a medium-ripe winter wheat with a great stem strength and high yield productivity. **Cellule** was medium-ripe strong tillering cultivar with high yield stability and nutrient utilization. **Aviron** was a semi-leafless winter pea cultivar with tendrils. Characterized by medium growing and excellent cold resistance.

In the year of 2020 a rainless April followed heavy rainfall in June. Probably this unequal distribution of rainfall physiologically affected the development of winter wheat. In April winter wheat was in the phase of tillering, which is decisive in the aspect of grain yield (ANTAL 2005a). The average rainfall and temperature are in figure 1.



1. Figure: an average rainfall and temperature in the year of 2019/2020 (Own editing, source: met.hu/eghajlat/magyarorszag_eghajlata/eghajlati_adatsorok/Szeged/adatok/havi_adatok)

Preceding crop was winter wheat. All of the parcels were sown on 22nd October 2019 and harvested on 10th June 2020. Nitrogen fertilization were in shared system in phase of tillering and stem elongation 30-30 kg ha^{-1}. After grain yield was measured, crude protein, gluten and Zeleny sedimentation value was determined by near-infrared-spectroscopy (NIR). Data from field experiments were analyzed by one-way analysis of variance.

RESULTS AND DISCUSSIONS

In all experiments the 2 numper of seeds of winter pea we considered as different applicaton. First of all we wanted to know, whether the biological N_2 fixation by pea has an effect to the grain yield of winter wheat compared with pure stands or pure stands with fertilizer. In table 2, we could see the grain yield both of the species in intercrop. Higher number of seeds resulted higher grain yield of winter wheat, except of pure wheat plots of Cellule. Between the 2 winter wheat species, Cellule gave higher grain yield than GK Szilárd, except of Aviron 1 million seed ha^{-1} application. Pure wheat with fertilizer treatment has the greatest yield of all the applications. GK Szilárd mixed with winter pea had more grain yield than the pure wheat parcel. In contrast Cellule mixed with winter pea didn't reach the pure wheat parcel's level, this assumed that overcompensation of seed density made yield depression.

Table 2

Grain yield of the applications

			Applications			
			Pure wheat 0 N	Aviron 60 seed m^{-2}	Aviron 100 seed m^{-2}	Pure wheat with fertilizer
Number of seeds of winter wheat	300 seed m^{-2}	GK Szilárd	3,81[a]	3,86[a]	3,36[a]	4,85[b]
		Cellule	4,89[b]	3,89[a]	3,28[a]	5,43[b]
	500 seed m^{-2}	GK Szilárd	4,02[a]	3,93[a]	4,1[a]	5,34[b]
		Cellule	4,86[a]	4,5[a]	3,99[a]	5,97[b]

The smallest grain yield has the winter pea cultivar, Aviron with 100 seeds m^{-2} parcels pairing Cellule 300 seeds m^{-2} (3,28 t ha^{-1}), then the highest value was Cellule in pure stands with fertilizer plots (5,97 t ha^{-1}) by 500 seeds m^{-2}. In 2 cases GK Szilárd has 1% and almost 2% better values against the unfertilized plots in the mix of 300 seeds m^{-2}-Aviron 60 seeds m^{-2}, and 500 seeds m^{-2}- Aviron 100 seeds m^{-2}. But we couldn't prove by statistically. Winter wheat and winter pea in plant association gave always smaller yield than the fertilized plots. Compared to the highest yield parcel it was 75% less than Cellule with 300 seeds m^{-2}-Aviron 60 seeds m^{-2}mix and 66% less than Cellule 500 seeds m^{-2}-Aviron 100 seeds m^{-2} combination. Statistical difference by p=0,05 were only in fertilized pure wheat plots and the other trial fields. There were no difference between the two cultivars statistically. We could determine in Cellule: further increase plant density the less grain yield we obtained. This overdensity could make crop depression.

We observed inner content values of winter wheat (crude protein, gluten and Zeleny) to compare the effect of fixed N_2 of the mixed plots to the fertilized experimental fields (table 3). Based on our examination we have to notice in terms of crude protein GK Szilárd with 300 seeds m^{-2}close to the control plot in both winter pea mixed parcels. It was not far behind the fertilized plot. It was similar in the other winter wheat variety, Cellule. In the case of Aviron 60 seeds m^{-2}, it was higher values than pure stands. In combination of 500 seeds $m^{-2}$of GK Szilárd and Cellule with Aviron 100 seeds m^{-2}shown better results than the control experiments. In summery GK Szilárd 500 seeds m^{-2}-Aviron 100 seeds m^{-2} combination producted more than 5% higher value, Cellule 300 seeds m^{-2} with Aviron 60 seeds m^{-2}parcel 0,7%, and Cellule 500 seeds m^{-2}-Aviron 100 seeds $m^{-2}$was better in 0,2%. We couldn't prove this difference statistically by p=0,05 , fertilized parcels provided the highest percentage of crude protein.

Table 3

Crude protein values in the applications

			Applications			
			Pure wheat 0 N	Aviron 60 seed m^{-2}	Aviron 100 seed m^{-2}	Pure wheat with fertilizer
Number of seed of winter wheat	300 seed m^{-2}	GK Szilárd	10,35[a]	10,33[a]	10,28[a]	11,03[a]
		Cellule	10,85[a]	10,93[a]	10,8[a]	11,4[a]
	500 seed m^{-2}	GK Szilárd	9,88[a]	9,65[a]	10,45[a]	10,98[a]
		Cellule	10,45[a]	10,28[a]	10,48[a]	11,15[a]

Gluten determine the bakery value from quality parameters of wheat. The two winter wheat varieties: GK Szilárd and Cellule 500 seeds m^{-2} combined with Aviron 100 seeds m^{-2} reached higher values (7% and 0,6%) than the pure stands. So we have two results, which surpassed the unfertilized parcels. Statistical analysis performed to gluten, but concluded with a similar results just like crude protein. In table 4 we can see the gluten values of winter wheat varieties in intercrop with winter pea. Differences between varieties and applications were so small, then we couldn't prove them statistically. The best percentage were always in fertilized plots. It was 21,15% in the parcel of Cellule 500 seeds m^{-2}.

Table 4

Gluten values of winter wheat varieties in intercrop with winter pea

			Applications			
			Pure wheat 0 N	Aviron 60 seed m^{-2}	Aviron 100 seed m^{-2}	Pure wheat with fertilizer
Number of seed of winter wheat	300 seed m^{-2}	GK Szilárd	19,08[a]	18,8[a]	18,83[a]	20,55[a]
		Cellule	20,65[a]	20,53[a]	20,23[a]	22[a]
	500 seed m^{-2}	GK Szilárd	17,9[a]	16,8[a]	19,2[a]	20,15[a]
		Cellule	19,4[a]	18,83[a]	19,53[a]	21,15[a]

Zeleny sedimentation value a method for estimating a quality of wheat.We observed this value with the statistical method what we already used it before depending varieties and treatments. Here we got neither the treatments and varieties has no effect on Zeleny sedimentation values. By p=0,05, there were no statistical differences. We could see in table 5 at sowing density 100 seeds m^{-2} of Aviron in all the mixed parcels surpassed the pure stand values. In addition in the case of Cellule 300 seed m^{-2} combined with either sowing density of Aviron gave higher results. The highest value of the plant associations represented the already mentioned Cellule 300 seed $m^{-2}$with Aviron 60 seed m^{-2}combination (41,95 ml). If we were sowing Cellule 300 seed m^{-2} alone, we got 40,85 ml. This is 2% less than Aviron 60 seed m^{-2}, 1% less than Aviron 100 seed m^{-2}, and almost 6% less than the fertilized plot. Winter wheat and winter pea in intercrop never reached the values of the fertilized parcels, which were still repesented the best results.

Table 5

Zeleny sedimentation values of intercropped species and their applications

			Applications			
			Pure wheat 0 N	Aviron 60 seed m^{-2}	Aviron 100 seed m^{-2}	Pure wheat with fertilizer
Number of seed of winter wheat	300 seed m^{-2}	GK Szilárd	38,13[a]	37,78[a]	38,5[a]	40,13[a]
		Cellule	40,85[a]	41,95[a]	41,35[a]	43,28[a]
	500 seed m^{-2}	GK Szilárd	36,03[a]	35[a]	39,05[a]	40,13[a]
		Cellule	40,03[a]	39,48[a]	40,55[a]	42,98[a]

CONCLUSIONS

Intercrop is a special way of plant association. Our goal were to examine whether winter wheat and winter pea can be associated in a well nourished experimental station in Szeged-Öthalom. We were sowing, nursing and harvested at the same time together. The required machinery park is the same as cereals. There is no need machinery investment. URBATZKA et al. (2011) preferred pea in intercrop instead of monocrop, because pea in monocrop has poor resistance to weeds, lodging, fungal desease and yield instability. GRONLE et al. (2015) confirmed that pea in intercrop prevented from these difficulties. We experienced the same as them: there were no significant desease or weeds. Winter wheat was suitable for supporting winter wheat. Winter pea has an excellent cold resistance. PELZER et al (2016) observed that pure stands has less yield than in mixed parcels. Mostly we have to agree with her, but in two cases grain yield were less in the unfertilized plots. In both cases the winter wheat variety was GK Szilárd. This variety has great stem strength and high yield productivity. It suggested that GK Szilárd is suitable for every sowing density even in such extreme weather conditions like in the spring of 2020. From GK Szilárd 300 seeds m^{-2} with Aviron 60 seeds m^{-2} and GK Szilárd 500 seeds m^{-2} combined Aviron 100 seeds m^{-2} parcels harvested more crops from pure stands. Although these differences were very small, and we couldn't prove them statistically by p=0,05. The highest values always were in still the fertilized parcels. In the future these attempts may serve as an example to evolve an alternative technology to replace nitrogen fertilizer partially. As ABI-GHANEM et al. (2011) presumed that increase nitrogen fixation by legumes can be decrease the quantity of fertilizer. Another remarkable finding was about the other variety: Cellule. This is a strong tillering cultivar with high yield stability and nutrient utilization. When we further increase plant density from 300 seeds m^{-2} to 500 seeds m^{-2} ,the less yield we obtained. This overdensity could make crop depression. Because of the growthhabit of this variety, it makes less suitable for high sowing density. FUJITA et al. (1992) emphasized that plant type and structure plays a key role of biological N_2 fixation and yield of the associated legume, and thereby the effectiveness of plant association. We agree that the choice of variety and its combinability affects subsequent crop formation.

PELZER et al. (2016) noticed that wheat-pea intercrop with fertilizer increased only grain yield of the wheat, but has no efffect on inner content values. We examined crude protein, gluten and Zeleny sedimentation value. The highest results were in pure stands with fertilizer plots, but there were no statistical diferrences between this parcels and the others.

Inner content values can be said to be unformly average. We had higher results in mixed plots than the pure stands-especially both winter wheat varieties 500 seeds m^{-2} with Aviron 100 seeds m^{-2} –what we did not prove statistically by p=0,05. Against PELZER et al. (2016) we did not observed differences between fertilized and unfertilized parcels in terms of inner content values. In the year of 2020 we have a drought April, which followed by very rainy May and June. This unequal distribution of rainfall might be affected the development of winter wheat. Winter wheat was in the phase of tillering in April. At this phase the number of spikelets per ears is formed, the beginning and develpoment of stem elongation controlled by late spring weather (ANTAL, 2005). In our results were less than the average grain yield and inner content values, which seemed in pure stands and fertilized plots. But also appeared in mixed parcels.

Winter wheat and winter pea intercrop is a special form of plant association which based on complementarity, offers greater financial stability and allows lower inputs which minimizing environment impacts of agriculture.

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