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Evaluation of the Development Process of Winter Wheat (*Triticum aestivum* L.) and Winter Pea (*Pisum sativum* L.) in Intercropping by Yield Components

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Abstract: The future of wheat production depends on our ability to adapt to changing growing conditions. It is expected that intercropping will be more emphasized where natural source of nitrogen may increase the resilience of cereals. Our investigation was made in two growing seasons (2020–2021, 2021–2022) with three winter wheat varieties (GK Szilárd, Cellule, GK Csillag) and a winter pea variety (Aviron) in Szeged-Öthalom. Each plot was 10 square meters in four repeats in randomized block design. We used a seed mixture of both species with three sowing densities. In this study, we represent a development process of two winter-sown species, then yield components evaluated by cumulative yield production analysis and multivariate regression. Mixtures were only beneficial for wheat in the case of GK Szilárd 50% and Aviron 75%, Cellule 75% and Aviron 100% (in 2021), Cellule 100% and Aviron 50% (in 2022), GK Csillag 75% and Aviron 50%. The yield was determined by the number and weight of grains in both species (and also number of pea pods). Knowledge of the development process of the companion plants is a key issue in creating an effective intercrop. This self-sustaining, low input and energy efficient cropping practice has a great potential in temperate areas.

Keywords: intercrop; yield stability; sustainable agriculture; wheat; pea

Citation: Vályi-Nagy, M.; Rácz, A.; Irmes, K.; Szentpéteri, L.; Tar, M.; Kassai, K.M.; Kristó, I. Evaluation of the Development Process of Winter Wheat (*Triticum aestivum* L.) and Winter Pea (*Pisum sativum* L.) in Intercropping by Yield Components. *Agronomy* **2023**, *13*, 1323. https://doi.org/10.3390/agronomy13051323

Academic Editor: Christos A. Dordas

Received: 27 March 2023
Revised: 3 May 2023
Accepted: 5 May 2023
Published: 9 May 2023

1. Introduction

Global climate change is a part of our everyday life. A continuous rise in temperature and increasing frequencies of extreme weather events suggest that is not an isolated phenomenon [1,2]. Global climate models predict the mean ambient temperature to increase 2–4 °C by the end of twenty-first century [3–6]. Even a 1 °C increase in average temperature has a negative effect on the sexual reproduction of most annual plants [7]. Unfavored distribution of precipitation may change the suitability of the varieties at the present cultivation method, change the need for plant protection, lead to a decrease in cultivated areas and can cause higher yield variability [7–9]. These negative effects of climate change constantly test the adaptability of our cultivated plants [1,8], and future opportunities of crop production are largely determined by whether we will be able to change our currently established cultivation habits.

In the second half of the 20th century, farmers all around the world changed legume rotations to synthetic N fertilizers [10]. The shift from natural nitrogen sources to industrial ones made significant changes in agriculture, which reduced diversification and created dependency on artificial fertilizers [11,12]. For many, the use of nitrogen fertilizer was considered a guarantee for high yields, but their extensive use causes environmental damage [13,14]. In the last few years, thanks to the growing awareness of environmental damage, there is increased interest in new cultivation methods [15–17]. Intercropping is defined as cultivating two or more crops in the same place at the same time [18]. This old cropping practice is not widespread in temperate agroecosystems [13,17,19], but it was common in developed countries before the intensification of agriculture [15]. The reintroduction of legumes in cropping systems is a promising way to break crop effect in cereal-rich rotations, avoid environmental hazards and maintain a high production level through their nitrogen fixing ability [10,20–22]. Most legumes have been ignored by producers, advisors and value chain agents in the EU [23]. The continuous area decrease can be explained by their being less economically competitive compared with more profitable cereals [24,25]. In contrast, field pea is one of the ten most frequently used companion plants in intercropping [15,26]. According to Hauggaard-Nielsen [27], varieties not only performed differently in pure stands and intercrops, but also the choice of pea type determined the relationship of the companion plants to each other. Most arable crops have been bred for sole cultivation, which explains that these varieties may not necessarily be suitable for intercropping [19,24,28]. Field pea is an important cool season grain legume in Europe [29–31] which has strong sensitivity to weather conditions [6,32,33]. The response to abiotic stresses depends to a large extent on the developmental stage of the plant [4]. In terms of plant association, the definition of critical phase is essential in order to coordinate the cultivation of companion plants [34]. Shifting from spring peas to autumn varieties is an opportunity to adapt to environmental factors [35–37]. Winter-hardy varieties, in contrast to spring ones, usually have earlier phenological development; thus, drought can be avoided and, due to their longer growing season, improved yield and higher yield stability can be ensured [35,38,39]. Pea yield also depends on leaf morphology [40]. Today, semi-leafless varieties account for more than 80% in the European Union [29]. A modified canopy helps plants to remain upright and conserve water by minimizing evapotranspiration, thereby keeping the canopy cool and mitigating heat stress [28,41].

The benefits of intercropping, such as yield stability; better growth resource utilization; improvement of soil fertility; lodging resistance; and a reduction in weeds, pest and disease incidence compared with sole crop, have been investigated by many researchers [17,19,21,42]. However, there are very few articles that have dealt with the development process of the companion plants in intercropping. The companion plants are usually from different families, which complicates plant protection, nutrient and fertilizer application. For this reason, the aim of this study was to present a wheat and pea intercrop grown in winter season in southern Hungary with a focus on their parallel development and on the change of yield components and their role in yield formation. Our findings can help the selection of the appropriate varieties to be used in intercrops in the future, thereby contributing to the spread of this new cultivation practice.

2. Materials and Methods

2.1. The Background of the Experiment

Our field experiments were made in two consecutive growing seasons (2020–2021 and 2021–2022) at the Applied Agronomy Research Station of the Hungarian University of Agriculture and Life Sciences in Szeged-Öthalom. The experimental design was a randomized block design in a split plot arrangement in 4 repeats, where the size of each plot was 10 square meters. Soil characteristics were meadow chernozem soil with a humus content of 2.8–3.2% and slightly alkaline reaction (pH = 7.9). It is well-supplied with nitrogen (24.0 mg/kg), phosphorus (248 mg/kg, and potassium (209 mg/kg). The first crop was winter wheat in both years. All the winter wheat and pea seeds were dressed, but winter pea was not inoculated. There was no organic fertilizer application at the experimental site in the last 5 years; however, autumn multinutrient fertilizer was applied at the rate of 200 kg ha^{-1} (complex NPK (15:15:15)). In this experiment, we compiled a seed mixture of 3 varieties of winter wheat (GK Szilárd, Cellule, GK Csillag) and one variety of winter pea (Aviron). The mixtures were formulated via commonly used and widespread sowing densities in pure stands, where 5 million seed ha^{-1} was considered 100% in the case of winter wheat and 1 million seed ha^{-1} for winter pea, respectively. We determined the same for 50% and 75% sowing densities. The exact amounts of the sowing density are summarized in Table 1.

Table 1. Sowing densities of the plant association.

		Number of Seeds of Winter Pea			
		0 Seed m^{-2}	**50 Seed m^{-2}**	**75 Seed m^{-2}**	**100 Seed m^{-2}**
Number of seeds of winter wheat	0 seed m^{-2}	-	0:50	0:75	0: 100
	250 seed m^{-2}	50:0	50:50	50:75	50:100
	375 seed m^{-2}	75:0	75:50	75:75	75:100
	500 seed m^{-2}	100:0	100:50	100:75	100:100

In the first growing season in 2020–2021, crops were sown on 21 October and the following year in 2021–2022 on 19 October with a Wintersteiger Plotman (Wintwersteiger Gmbh, Ried, Austria) parcel grain machine. Seeds of the mixtures were sown simultaneously. Row width was 12.5 cm and sowing depth was approximately 4–5 cm. Plants were sprayed against disease, insect and weeds one or two times in each growing season according to thresholds of the infestation.

GK Szilárd is an awnless medium-ripe winter wheat variety with a good adaptability to environmental conditions and high yield productivity. It has great stem strength, which is suitable for pea support. Cellule is also a medium-ripe strong tillering variety with high yield stability and nutrient utilization. It has high yield productivity even in unfavorable conditions. GK Csillag is an early ripe winter wheat variety with a balanced crop, evenly ripened and easy to thresh. It is one of the varieties that has grown in the largest area in Hungary. Aviron is a semi-leafless winter pea variety with tendrils. It is suitable for both feed and human consumption. It is characterized by medium growing and excellent winter hardiness. It has rapid initial development and good disease resistance.

Single-stage harvest was in full ripening stage (BBCH 89) on 1 July 2021 and 22 June 2022 using the Wintersteiger plot combine.

2.2. Weather Conditions

In Figure 1, the deviation from the average precipitation of the 10 years before the experiment is shown in the two growing seasons (2020–2021 and 2021–2022). The unfavored distribution of precipitation can be seen, especially in the second year, where the amount of rainfall in spring and summer was far below the average of the last 10 years.

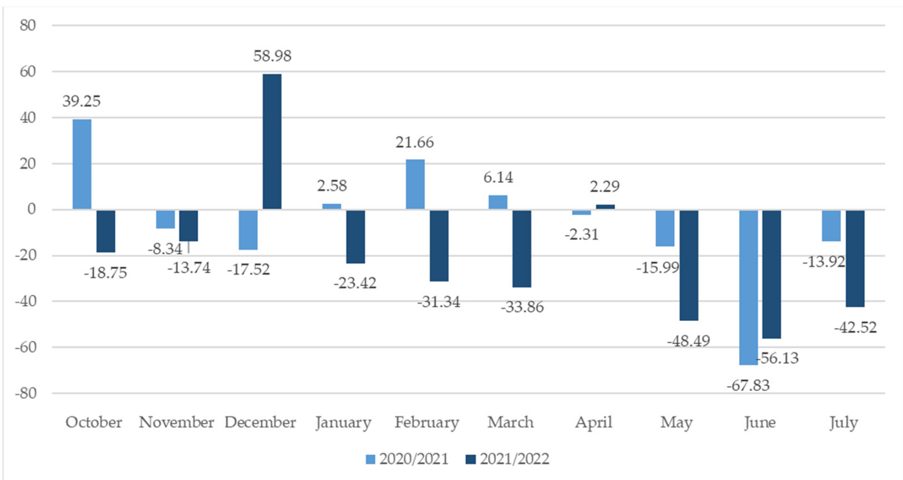

Figure 1. Deviation of precipitation (mm) in the 2 growing seasons compared with the average of the last 10 years before.

Figure 2 shows the deviation of the temperature in the 2 growing seasons in 2020–2021 and 2021–2022 compared with the average of the last 10 years before. In both years, we had a particularly mild winter. The measured temperatures in December–January and February were 1 or 2 degrees warmer than the average, which was replaced by a milder spring. By the time of harvest, a warmer period followed again.

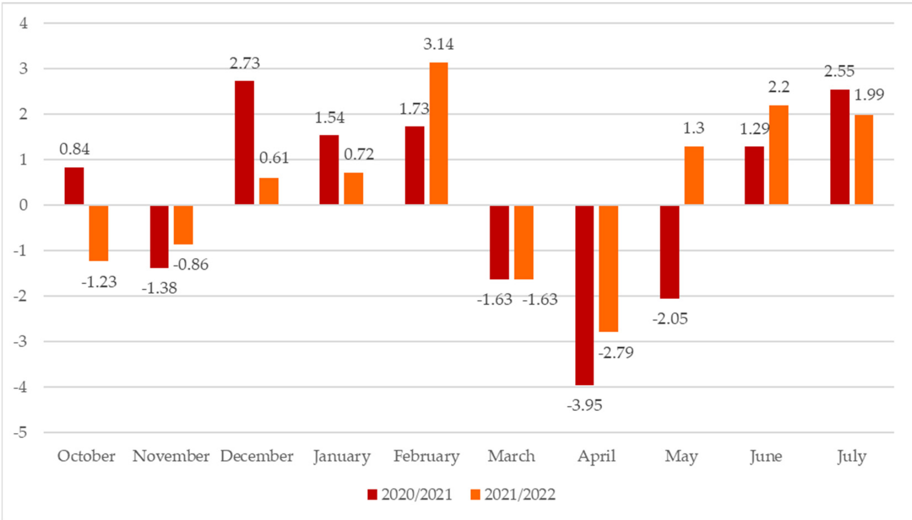

Figure 2. Deviation of temperature (°C) in the 2 growing seasons compared with the average of the last 10 years before.

2.3. Plant Sample Collection

Collection of full rooted plant samples was at the end of the growing season—29 June 2021 and 21 June 2022—from a unit area (1 m^2) from each parcel before harvest (at the time of full maturity of wheat BBCH 89-92). Plant samples were processed manually with a hand scale, and the yield components were determined from 1 m^2, which means in the case of winter wheat the plant, shoot, ear, spikelet, grain numbers and grain weight, and in the case of winter pea the plant, shoot, pod, grain numbers and grain weight.

2.4. Statistical Analysis

The yield components were evaluated with multivariate regression using SPSS v.27. The development of the plants was evaluated with Sváb-type cumulative yield production analysis [43,44]. In this analysis, the individual components refer to a unit area, and they follow the development stages of the plant. Yield components are the final phase products of the development stages, which make the entire development process visible. In a graphical representation of the yield components, the horizontal axis (x) shows the yield components from a given area (1 m^2), and the vertical axis (y) shows the percentage values of yield components of the associated plots compared with the base value (=in our experiment it means the pure parcel). Connecting the final end products with a line, it can be seen the direction and the intensity of the development of winter wheat and pea. It can be concluded from the development of the yield components not only the characteristics of the variety, but also as a result of the applied agrotechnology or the weather of the year.

2.5. Observations on Phenology of the Companion Plants

We carried our field observations during the growing season to investigate the development of the companion plant in plant association. Crop phenophases were determined with visual observations using the BBCH-identification keys of cereals and peas [45,46]. Field observations were made in spring 6 times in 2021 (10 and 31 March, 26 April, 11 and 26 May, 10 June) and 5 times in 2022 (17 March, 11 April, 2 and 16 May, 3 June).

3. Results

3.1. Cumulative Yield Production Analysis for Winter Wheat

The cumulative yield production analysis is discussed per variety and per sowing density. The development phases of the two examined years are graphically represented beside each other. In the case of the lowest seeding density of the GK Szilárd variety, the highest yield was achieved with the 75% combination of Aviron (Figure 3), while in the year 2022, development stages throughout the entire crop cycle were above the reference level; in 2021, the positive development started from the number of spikelets. The 100% mixture of winter pea 'Aviron' showed an upward trend, but exceeded the control level (by 6%) only in 2022, while the 50% combination crossed the control level for the ear and spikelet numbers, but in the grain weight phase had less values compared with the pure stands.

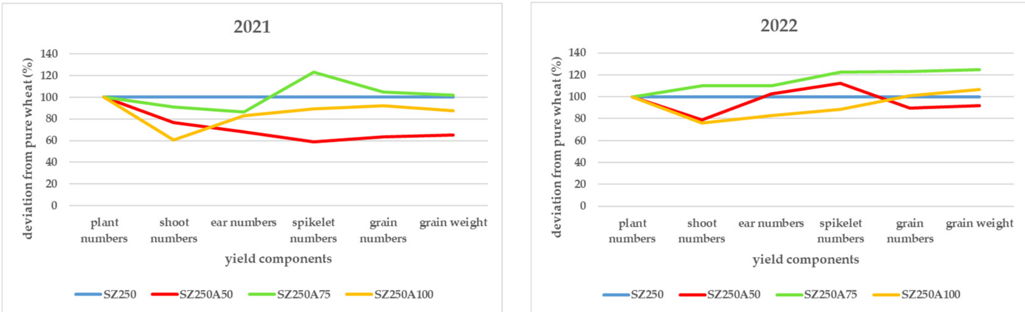

Figure 3. The development stages of the 50% sowing density of GK Szilárd (blue line) compared with the combination of 50% (red line), 75% (green line) and 100% (yellow line) Aviron in 2021 and in 2022.

If the same winter wheat variety at 75 % sowing density was mixed with Aviron (Figure 4), contradictory results were obtained in the two studied growing years. In the first year, all seed mixtures achieved lower values compared with the pure stands. The negative development already started in the case of the shoot numbers and was maintained throughout the entire development process. In contrast, in the year 2022, from the beginning of the development, all the associated plots were high above the control values. The mixture of GK Szilárd 75% and Aviron 100% sowing density exceeded the values of the control plot by 42% in terms of the grain numbers, and produced 24% more in terms of grain weight.

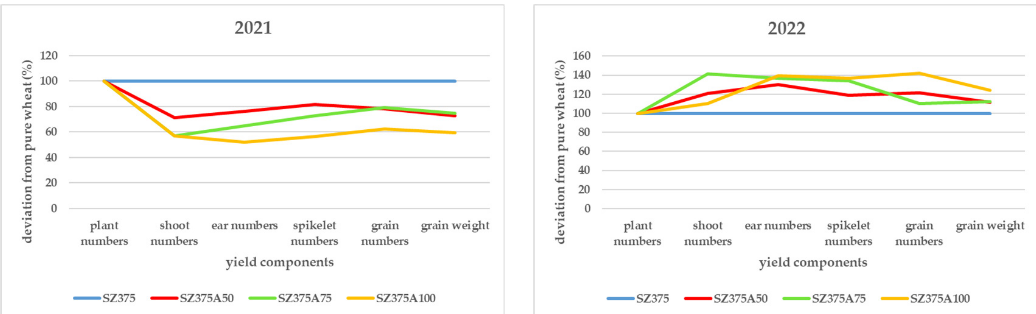

Figure 4. Development stages of GK Szilárd's 75% sowing density (blue line) compared with the 50% (red line), 75% (green line) and 100% (yellow line) Aviron mixture in the years 2021 and 2022.

It can be seen in Figure 5 that the combination of the highest sowing density of GK Szilárd and the lowest sowing density of Aviron was around the control values during the entire developing process in 2021. In addition, the other two associations remained well below the pure stands. The same cannot be stated for the year 2022, where the already-mentioned seed mixture surpassed the control plot by 19% in the case of seed weight. In the case of 100% sowing of GK Szilárd and 75% of Aviron, after a promising start we detected a decrease in terms of the grain numbers, but the grain weight was higher than the control. Finally, the third plant association remained below the control values.

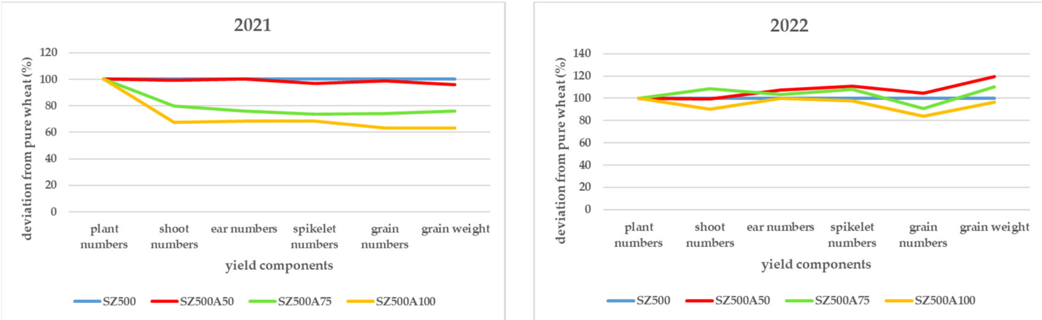

Figure 5. The development process of 100% sowing density of GK Szilárd (blue line) compared with the mixture of 50% (red line), 75% (green line) and 100% (yellow line) Aviron in 2021 and 2022.

In the case of the Cellule winter wheat variety, mixed results were obtained in the two examined years (Figure 6). In the first year, a mixture of 50% Cellule and 75% Aviron developed more strongly than the control parcel until the grain numbers phase. Then, it crossed the level of the control parcel and stopped below it by 9%. The same seeding density of winter wheat with 100% Aviron produced an outstanding grain numbers after the unfavorable development process. In this case, the seed weight did not reach the control level either, while the third association represented low level. In 2022, the 75% combination of Aviron with the lowest seeding density of Cellule did not even reached the level of the control plot except for the ear numbers phase. The 100% winter pea mixture also surpassed the pure stand level at this stage of development (ear numbers), and after low grain numbers, the grain weight finished with a positive development process. For all three plant associations, a fracture can be observed in the development process in the case of the grain numbers. The mixture with the smallest proportion of wheat and pea showed a positive development throughout 2022, until it finished with the second best result (at 107% of the control).

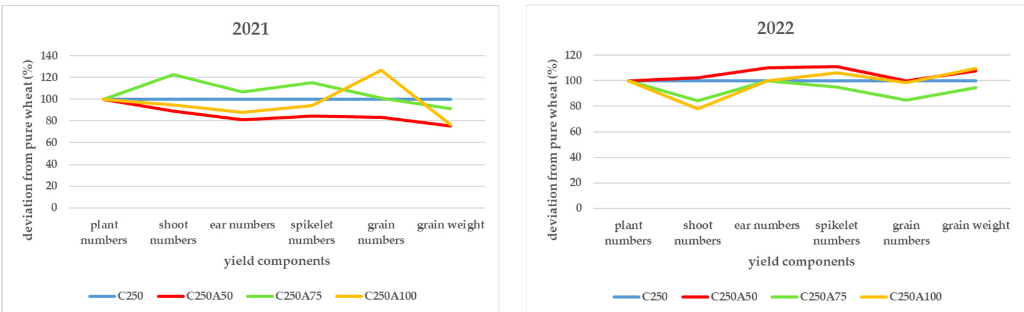

Figure 6. Development process in the case of 50% Cellule (blue line) compared with the 50% (red line), 75% (green line) and 100% (yellow line) sowing densities of winter pea association in 2021 and 2022.

It can be seen in Figure 7 the development process of the association of winter wheat 'Cellule' and winter pea 'Aviron'. In 2021, a roughly similar development could be examined for all winter pea mixtures. The higher rate proportion of peas in the intercrop, the more it exceeded the level of pure sowing. A negative development can be followed from the spikelet numbers phase, as a result of which the 100% pea mixture only exceeded the control parcel by 4%. In 2022, there were two major fracture points in the developmental process: one was the shoot numbers and another was the grain numbers phase. This wavy development curve appeared in all 75% Cellule mixtures. Mixtures with the two lowest sowing densities of pea achieved higher weight of grain values than the control plot by 9% and 11%.

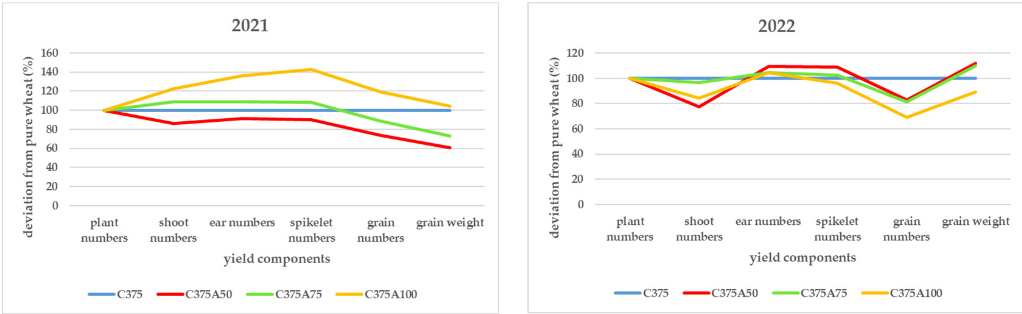

Figure 7. Development of the Cellule 75% sowing density (blue line) compared with the 50% (red line), 75% (green line) and 100% (yellow line) of winter pea mixture in the 2 examined years in 2021 and 2022.

In plant association, the 100% sowing density of Cellule and all the combinations of winter pea showed an increasing tendency in the shoot numbers phase in the first year (Figure 8). While the 75% mix of peas started to decline after that, the other two sowing densities remained at almost the same parallel development. By the grain weight phase, all the mixtures were below the control level. Compared with this in the second year, the plant association with the two highest pea sowing densities with 100% Cellule produced a completely negative development process. Only the Aviron 50% seeding density mixture exceeded the pure plot for grain weight by more than 24%.

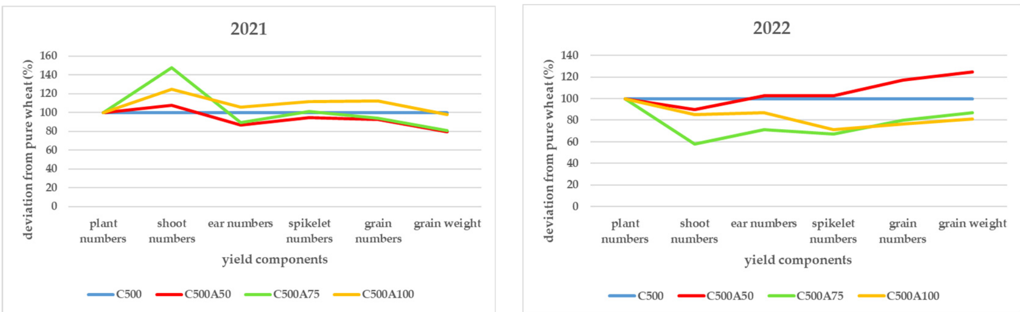

Figure 8. Development trends of the Cellule with the 100% sowing density (blue line) compared with the mixtures of 50% (red line), 75% (green line) and 100% (yellow line) pea in 2021 and 2022.

In the case of the last winter wheat variety, GK Csillag, 2021 ensured a mostly positive developmental process. This is true for its lowest sowing density and 50% and 75% winter pea sowing densities, respectively. In both cases, for the grain weight phase they exceeded the plot without plant association by 7%. In the mixture with the highest winter pea proportion, the development curve followed almost the entire length of the control. In contrast, in the following year, except for the initial development advantage of the mixture with the highest pea proportion, all plant associations performed below the values of the pure stands. These results can be seen in Figure 9.

Figure 10 illustrates the development curves of the 75% sowing density of the GK Csillag winter wheat variety with the variable winter pea ratio. In the first year, the pea seed mixture with 50% sowing density reached the highest measured compared with pure sowings. This meant an 11% increase in the grain numbers and a 4% surplus in the grain weight. In the case of the other two plant associations, a decreasing trend can be observed from the beginning of the development process. The same combination crossed the control plot level in the next year after an initial decline in the case of the 75% pea ratio mixture at the ear numbers phase and in the case of the 100% pea ratio mixture just before the grain number phase. The plant association with the largest proportion of peas exceeded the pure stand by 13% in the grain number stage, but in the grain weight phase already fell below the control level. The 75% sowing density of GK Csillag and the 50% mixture of peas showed a positive direction in the developmental process, then in the grain weight phase it reached a 19% higher value compared with the control.

In Figure 11, it can be seen the development of the highest sowing density of the GK Csillag variety and the combination of winter peas. In 2021, the 100% sowing density of wheat still tolerated plant association with all pea mixtures. The values measured in each development stage were close to the control level, although by the end of the developmental process only the 50% pea mixture retained its advantage. In the case of 100% sowing density of both varieties, despite the outstanding value in the spikelet numbers stage, this positional advantage does not appear in the later developmental phases. In 2022, the developmental processes of all the plant associations were deep below that of the control level. The two mixtures with smaller pea proportions moved almost parallel to each other. An increasing tendency can be observed in the grain numbers phase, which seems to decline again in the grain weight phase.

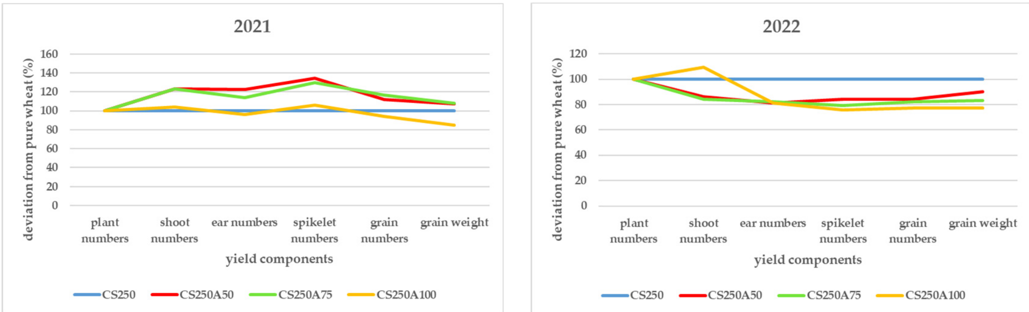

Figure 9. Development curves of GK Csillag with the 50% sowing density (blue line) compared with the mixture of 50% (red line), 75% (green line) and 100% (yellow line) winter pea in 2021 and 2022.

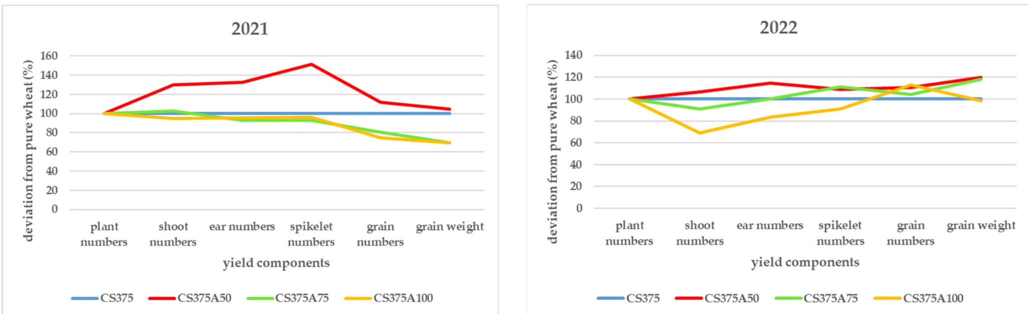

Figure 10. Development curves of the 75% sowing density of the GK Csillag (blue line) compared with the combination of 50% (red line), 75% (green line) and 100% (yellow line) winter pea in 2021 and 2022.

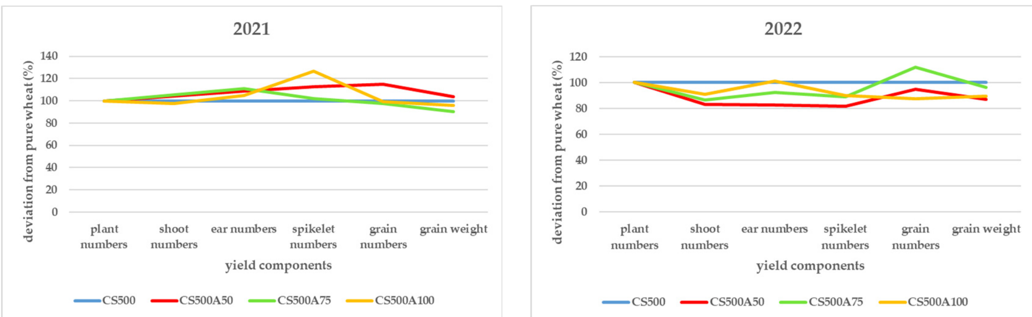

Figure 11. Development stages of the 100% sowing density of GK Csillag (blue line) compared with the association of 50% (red line), 75% (green line) and 100% (yellow line) winter pea in 2021 and 2022.

3.2. Results of Correlation between Yield and Yield Components of Wheat

The results of the Pearson correlation test illustrated in Table 2 show that the grain numbers (r = 0.52), weight of grains (r = 0.52), the spike numbers (r = 0.28) and the spikelet numbers (r = 0.43) were positively and significantly ($p < 0.01$) correlated with yield. However, the plant numbers (r = −0.17) and shoot numbers (r = −0.21) were not correlated with yield.

Table 2. Pearson correlation coefficients for yield and the examined yield components of wheat.

	Plant Numbers	Shoot Numbers	Spike Numbers	Spikelet Numbers	Grain Numbers	Weight of Grains	Yield
Plant numbers	1.00						
Shoot numbers	0.75 **	1.00					
Spike numbers	0.53 **	0.58 **	1.00				
Spikelet numbers	0.16	0.30 **	0.83 **	1.00			
Grain numbers	−0.09	0.04	0.61 **	0.77 **	1.00		
Weight of grains	−0.04	0.13	0.69 **	0.87 **	0.88 **	1.00	
Yield	−0.17	−0.21	0.28 **	0.40 **	0.52 **	0.52 **	1.00

** Correlation is significant at the $p < 0.01$ level (2-tailed).

3.3. Cumulative Yield Production Analysis for Winter Pea

In the case of winter pea, a negative development process can be observed for all seed mixtures. Although there were promising beginnings, the values finally fell below the control level in the stage of the pod numbers. Winter pea yield was very low in all cases, and the individual development processes were evaluated by winter wheat variety. If we examine only the plant association with the GK Szilárd variety, the most unfavorable combination of winter pea was realized with a mixture of 50% of it. In both years, the development of pea followed a downward trend line from the beginning. As we increased the proportion of peas in the mixtures, the shoot numbers increased. With the 100% mixture of peas, the shoot numbers reached a value 80% higher than that of the control in 2021. Then, for the pod numbers phase, the values of the mixtures began to decrease in varying proportions. This phenomenon can be seen in Figure 12 with the seed mixture of GK Szilárd winter wheat variety.

A significant difference between the two examined years was obtained in the case of Cellule variety (Figure 13). While a mixture of 50% sowing density of pea and 75% sowing density of Cellule significantly exceeded (154%) the control level in the shoot numbers phase in 2021, by then the same combination had decreased 63% below the pure stand in 2022. In the same way, the association 50% of pea and 100% of Cellule from the level of the pure stands greatly decreased in the following year (18%). The Aviron 75% with the Cellule 100% sowing density combination showed significantly higher values in the shoot number stage in both years (130% and 190%, respectively) compared with that of the control plot.

The mixture of Aviron 50% and GK Csillag with 75% sowing density exceeded the control level only in the year 2022 in the development phase of the shoot numbers (109%). While in the initial development phase in the first experimental year, the 75% mixture of Aviron and 50% and 75% of GK Csillag showed the same level as the pure plot, by the second experimental year, these values were reduced to 80%. The only plant associations with GK Csillag, which in both years exceeded the control plot up to the pod numbers stage, were Aviron 100% and GK Csillag 50% and 75% sowing densities. Starting from this development phase, a decreasing tendency can be observed, similar to the other winter wheat varieties. The results of Aviron's plant association with GK Csillag can be seen in Figure 14.

Figure 12. Developmental process of winter pea (blue line) compared with the mixture of GK Szilárd 50% (bright green), 75% (medium green) and 100% (dark green) in 2021 and 2022.

Figure 13. Developmental process of winter pea (blue line) compared with the mixture of Cellule 50% (bright green), 75% (medium green) and 100% (dark green) in 2021 and 2022.

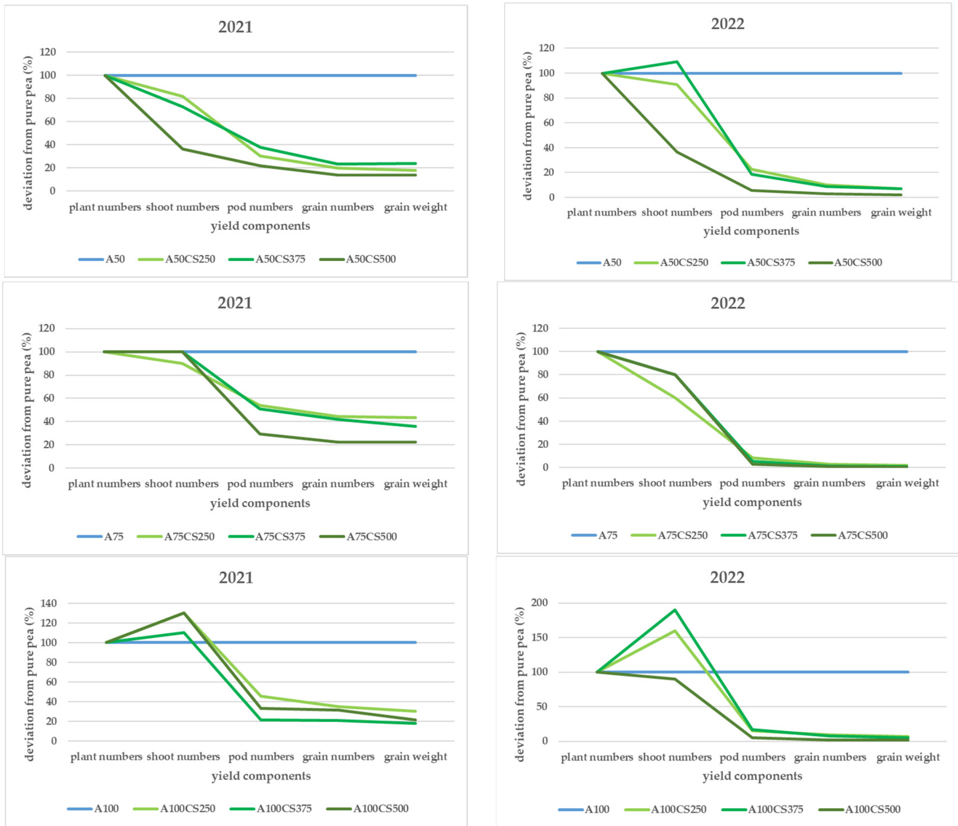

Figure 14. Developmental process of winter pea (blue line) compared with the mixture of GK Csillag 50% (bright green), 75% (medium green) and 100% (dark green) in 2021 and 2022.

3.4. Results of Correlation between Yield and Yield Components of Pea

Based on the results of the Pearson correlation test summarized in Table 3, the plant numbers (r = 0.28), pod numbers (r = 0.82), the grain numbers (r = 0.79) and the weight of grains (r = 0.80) were positively and significantly correlated with yield at $p < 0.01$. The shoot numbers was positively and significantly correlated with yield at $p < 0.05$.

Table 3. Pearson correlation coefficients for yield and the examined yield components of pea.

	Plant Numbers	Shoot Numbers	Pod Numbers	Grain Numbers	Weight of Grains	Yield
Plant numbers	1.00					
Shoot numbers	0.97 **	1.00				
Pod numbers	0.47 **	0.40 **	1.00			
Grain numbers	0.41 **	0.35 **	0.96 **	1.00		
Weight of grains	0.37 **	0.30 **	0.96 **	0.97 **	1.00	
Yield	0.28 **	0.24 *	0.82 **	0.79 **	0.80 **	1.00

* Correlation is significant at the $p < 0.05$ level (2-tailed); ** Correlation is significant at the $p < 0.01$ level (2-tailed).

3.5. Results of the Observation of Phenology and the Critical Stages of Winter Wheat and Pea

In our experiment, we used a seed mixture that was sown and harvested at the same time. It can be seen in Figure 15 that winter pea flowered earlier than winter wheat; at this time, wheat was in the booting stage. At the time of wheat anthesis, pea was in the pod filling stage and achieved physiological maturity much earlier than wheat. Growing season was 254 days in 2021, while it was 247 days in 2022. Development stages in the second experimental year alternated quickly; thus, the growing season was shortened by one week.

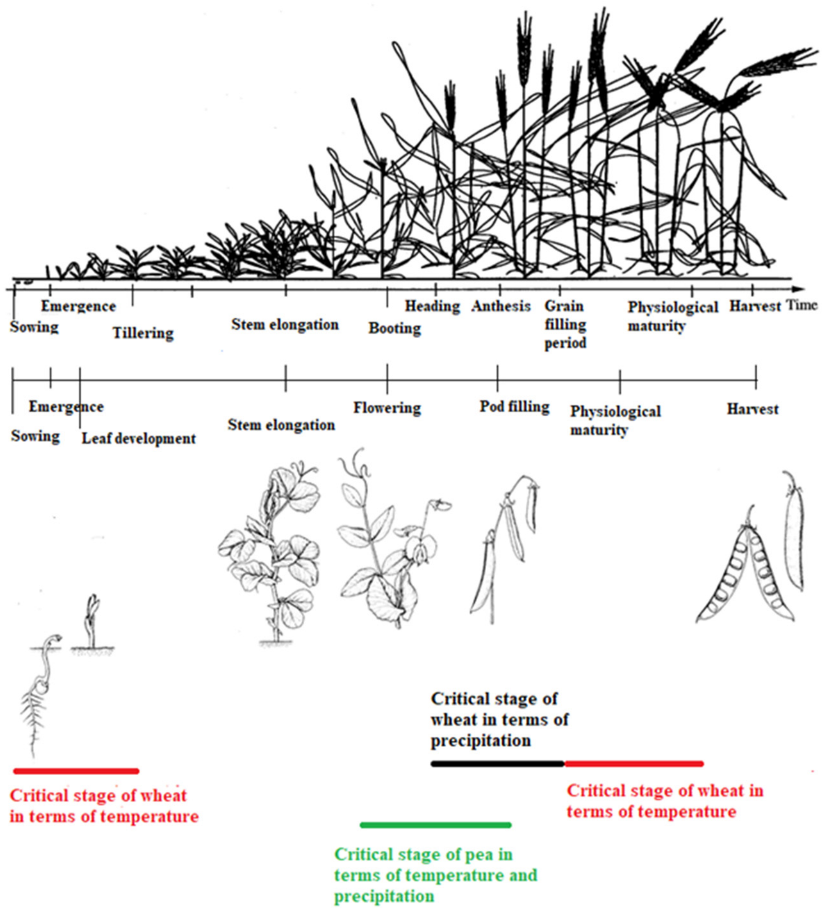

Figure 15. Phenological development and critical stages of winter wheat and pea (own editing).

Wheat is most sensitive to temperature in two critical periods: one is the vernalization and the other is 6–8 days before anthesis and during reproductive development [47,48]. The threshold value in the time of germination is 15–20 °C, while during tillering phase the optimal temperature is 13–18 °C. For the flowers to open, they need at least 11–16 °C [49]. The maximum temperature wheat can endure without damage is 30 °C, and regardless of the development phase, heat stress lasting 5 days can cause crop failure [50]. In 2021, there were 13 consecutive days when the temperature exceeded the threshold temperature. In contrast, in 2022, there were six separate days in the same period. Higher temperature accelerates the onset of anthesis [50]. In case of precipitation, the most vulnerable periods are the phenophases of heading and flowering [48]. Field pea is a heat-sensitive grain legume. It requires an even water supply for its initial development, but its maximum water demand occurs during the flowering and pod filling stages. During flowering, moderate heat is required, as high temperature accelerates the ending of the flowering time (threshold 25–28 °C daily air maximum in the field). Pod filling and yield are reduced [32,33,41,51].

4. Discussion

The unpredictable weather phenomena, dependence on artificial fertilizers and fluctuating market demand made farmers vulnerable from several sides [44]. In this situation, the transformation of the present cultivation methods is not only an important issue from an economic point of view, but in the long term it also serves to comply with environmental awareness and the principle of sustainability [16,52]. In most cases, research works have defined the nutrient requirement for the cultivation of the given plant and ignored the previous crops and soil conditions [53]. Leguminous plants play a prominent role in cropping structure and crop rotation. Their presence significantly increases the level of yield and yield stability [54]. Research with intercropping has focused on the interaction between companion plants and most often only examines yield. There is no specific BBCH code for winter peas or parallel development stages [26]. The knowledge of the development process is essential to coordinate the cultivation of different species together. Therefore, in our study, we attempt to present the development process of two species. One of the strategic advantages of winter pea varieties is earliness [35]. Winter-sown peas can usually be harvested before winter barley, which is beneficial due to the distribution of work processes and also provides an opportunity to avoid drought and high temperature stress in late spring [38,55]. This could be especially important for pea, because it has increased sensitivity to high temperature and low heat tolerance [6,32,56]. The year 2021 was a moderately warm year, followed by a severe drought in 2022. Consequently, in 2022, by the time winter wheat reached physiological maturity, winter pea plants dried from below and the seeds began shedding. These symptoms clearly indicate elevated temperature. Many studies have dealt with the effect of heat stress and water deficit, which has been reported to have similar effects [6,31,33,51,56,57]. In field pea, flowering nodes are formed sequentially from the bottom to the top. Thus, sequential pod forming along the stem provides a picture of the development of the pea [58]. We could see in the second experimental year that the top floral buds were not fully developed and the flowering time was shortened by a week. A shorter vegetative phase coincides with the findings of Poggio et al. [56] and Sita et al. [31], that exposure to high temperatures accelerates the ending of the crop cycle and causes forced maturity. In the case of unfavorable weather conditions in the phases of flowering and pod filling, a decreased number of seeds per pod is attributed to heat stress [9,30,31,51,57]. In contrast to this, cumulative yield production analysis showed a downward trend line, which already occurred in the pod numbers stage not only in the terminal drought year, but also in the moderately warm year. This phenomenon implies that, although high temperature during flowering can be a cause of yield variation [51], it is more likely that, in our experiment, winter wheat had an effect on winter pea. Mixtures show differences in their initial development compared with the control plot. In terms of the shoot numbers, the GK Szilárd variety with 75% and 100% sowing densities of winter pea, the Cellule variety with 75% and the GK Csillag with 100% pea proportion can be considered an effective plant association. This reflects the tolerated proportion of Aviron by the tested wheat varieties. Based on the results of the Pearson correlation test, yield components that determine pea yield were the pod numbers ($r = 0.82$), the grain numbers ($r = 0.79$) and the weight of grains ($r = 0.80$). The threshold value for pea is usually 25–28 °C in the field [32,41]. In 2022, the number of warm days above the threshold value was 10 days more than the previous year, but warming appeared gradually. According to Bányai [4], because of acclimation plants are able to survive above the optimal level. It is likely that winter pea produced a yield due to this basal thermotolerance. Some studies have mentioned that semi-leafless peas, thanks to their modified leaflets into tendrils, help to prevent lodging and conserve water by minimizing evapotranspiration [40,41]. In our experiment, the choice of the winter pea type alone did not prove to be sufficient against weather conditions. Pea yield is a multi-faceted complex of environmental variables [51]. The variety of the selected winter wheat companion plant had at least the same role for yield loss.

The high ability of wheat in a wide range of ecological conditions made it the most important crop in the world. Climate scenario forecasts predict a continuous rise in temperature and the decline of annual precipitation escorted by extreme meteorological events [1]. The permanent lack of water in winter could not be compensated by the rainfall during the vegetation period; it has a similar effect on yield as summer drought [59]. Severe water shortage also occurred in our experiment, which can be attributed to the effect of abiotic factors rather than to plant association. In the year 2022, which was the driest year in the last 10 years, except for December, winter wheat struggled with water shortages for most of the year. This was reflected in the increased number of sterile shoots and withered plants from below during grain filling. Many studies reported that drought stress reduced the number of spikes and grains per plant [60,61], and the response to post anthesis drought differed between the varieties [62]. We also experienced that post anthesis stress caused a significant decrease in the grain numbers and grain weight from the first year to another, and there were slight numerical differences between the individual winter wheat varieties. Wheat is often exposed to short periods of high temperatures during the flowering and grain filling period [50]. High temperature is also accelerating and shortens the period of flowering and grain maturity [60], at the same time reducing plant height and the number of productive shoots per plant [4,61]. Based on our observations, we confirm that higher temperature speeds up wheat plant flowering and maturity and caused forced maturity, which was already seen in the case of winter pea. The time of the harvest was determined by the ripening of the wheat, which was a week earlier in the second year. Despite the adverse effect of the environmental factors, wheat yield losses were not as great as those in pea, which suggest that intercropping increased the resilience of wheat. Our results imply that intercropping in this composition actually benefits winter wheat. In summary, during the experimental years we found a different seed mixture as ideal for each winter wheat variety. We chose GK Szilárd because of its good adaptability to environmental factors and great stem strength. In plant association, its 50% sowing density and Aviron's 75% sowing density produced stable results in both years. In the other cases, we obtained a variable yield or very similar values to the control. Cellule had high yield stability and nutrient utilization in pure stands even in extreme weather events. The two growing seasons were different from each other. While in 2021 a mixture of Cellule 75% and Aviron 100% proved to be the most successful, until then in 2022, the association of 100% Cellule and 50% Aviron achieved the highest values. The crop year effect was most noticeable in this winter wheat variety. Our third variety, GK Csillag, has been sown in the largest area in Hungary. It has a balanced crop with uniform ripening in pure stand. It provided this stable yield in both years with its 75% and Aviron 50% combination. The results of the Pearson correlation showed a moderately strong relationship between grain yield and the grain numbers ($r = 0.52$) and the weight of grains ($r = 0.52$). In the case of the number of spikes ($r = 0.28$) and the spikelet numbers ($r = 0.43$), they were positively and significantly ($p < 0.01$) correlated with yield. In contrast, the plant numbers ($r = -0.17$) and shoot numbers ($r = -0.21$) were not correlated with yield.

5. Conclusions

Due to changing cultivation possibilities, new cultivation methods presumably have a greater role, which also complies with the directive of environmental awareness and sustainability. An effective winter wheat and pea intercrop has a great potential to increase yield stability even in the case of variable weather conditions.

Based on our results, we can state the following findings:

- It was the first time describing the developmental process of two winter-sown crops in intercropping, precisely defining the parallel development stages, as well as the time of the growing seasons and summarizing its critical stages.
- Each winter wheat variety tolerated the presence of winter pea in intercropping to a different extent. GK Szilárd 50% sowing density and Aviron 75% sowing density produced stable results in both years. In 2021, a mixture of Cellule 75% and Aviron 100% seemed more effective, while in 2022, the association of 100% Cellule and 50% Aviron achieved higher values. GK Csillag provided stable yield in both years with its 75% and Aviron 50% combination.
- Based on the Pearson correlation, the number and the weight of grains in wheat were decisive in terms of yield, which was influenced both by the weather of the given year and the presence of the companion plant. While extreme weather events mostly had a negative effect on crop formation, the presence of winter peas and their natural nitrogen supply alleviated these symptoms.
- From the point of view of winter pea, none of the plant associations could be said to be effective. According to the multivariate regression, the yield was determined by the pod numbers, the grain numbers and its weight. At the same time, despite the

sensitivity of weather conditions, the presence of the companion plant had a stronger negative effect in the pod filling stage, which could have been the reason for the drop in yield.

Author Contributions: Conceptualization, M.V.-N.; methodology, M.V.-N.; software, M.V.-N., M.T. and I.K.; validation, M.V.-N. and I.K.; formal analysis, M.V.-N.; investigation, M.V.-N., I.K., A.R., K.I., L.S. and M.T.; resources, M.V.-N.; data curation, M.V.-N.; writing—original draft preparation, M.V.-N.; writing—review and editing, M.V.-N., I.K., A.R., L.S., K.I., M.T. and K.M.K.; visualization, M.V.-N.; supervision, I.K., M.T. and K.M.K.; project administration, M.V.-N.; funding acquisition, M.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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