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THE EFFECTS OF DIFFERENT SOWING TIMES ON THE PHENOLOGICAL CHARACTERISTICS AND SEED YIELD OF THE PEA (*Pisum sativum* L.)

Feride ONCAN SUMER

Aydin Adnan Menderes University, Faculty of Agriculture, Department of Field Crops, Aydin 09100, Turkey
Corresponding author: fsumer@adu.edu.tr

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ABSTRACT

The pea is a legume with a high protein content and high nutritional value. In recent times, it has come to be consumed as a frozen and canned food as well as fresh. It has a special place among legumes because of its suitability for crop rotation. In Turkey, it is mostly grown as a winter crop in the western regions. Sowing takes place in the fall for the winter growing season. Determining the best sowing time is vital to avoid cold damage. This study was conducted over two years in 2020-21 and 2021-22 growing seasons in the field crops trial fields of Aydin Adnan Menderes University Faculty of Agriculture. During the study, the dry matter values and GDD (growing degree days) of four pea cultivars (Giresun, Mayer, Local 1 and Local 2) were calculated at four phenological periods (emergence, flowering, pod set and maturity) for three different sowing times (November 1, November 20 and December 10). In addition, the yield and yield characteristics and protein content were analyzed. Among the four varieties, Mayer (1.95t ha^{-1}) recorded the highest yield value, while Giresun (25.6%) achieved the highest protein content. The number of days to maturity, dry matter content and GDD values of the varieties at the different phenological periods varied with the sowing time. Higher GDD and dry matter content levels were measured in early sowing. The later the sowing, the shorter the period from pod set to maturation and the lower the dry matter content.

Keywords: dry matter, GDD, pea, seed yield, sowing time.

INTRODUCTION

The pea is one of the most important edible grain legumes, ranking third in the world with a cultivation area of 7 billion ha, and fifth in Turkey with a cultivation area of 679 ha (FAO, 2021). It has a high protein content (24-31%) and is rich in other nutrients, including amino acids that cannot be synthesized in the human body, vitamins (especially A, B, C and D), minerals, carbohydrates, phosphorus, calcium and above all iron. In addition to its importance in human and animal nutrition, the pea plant also has positive effects on soil fertility. Legumes enrich the soil with nitrogen by binding the free nitrogen in the air to the soil with the help of the Rhizobium ssp. bacteria in the soil. Higher nitrogen fixation can be observed in fall sowing than in spring sowing (Smytkiewicz et al., 2021).

Yield losses in pea cultivation vary from 30% to 60% depending on factors such as variety, sowing time, climatic conditions and location (McDonald and Peck, 2009). In regions with a Mediterranean climate and mild winters, pea sowing is carried out in the fall (Rubiales et al., 2009). Adjusting the sowing time in peas is important for good growth and higher yields (Ahmed et al., 2020). As a result of the long vegetation period in fall sowing, plants can produce higher yields than in spring sowing since sufficient leaf area is created and the leaves benefit from sunlight for a longer period (Silim et al., 1985). Although some studies suggest that seed yield and nitrogen fixation ability are limited in fall sowing due to the winter cold (Esser-Monning et al., 1995; Kessel and Hanter, 2000), others have observed that early sowing in the fall leads to higher yields than spring sowing (Doring and Reckling, 2018; Zboi´nska, 2018). In Central Europe, legumes are usually sown in spring. Both winter and summer beans are successfully grown in Austria, Germany and Switzerland (Flores et al., 2012; Neugschwandtner et al., 2020), while in European regions with less frost, such as France or Spain, fall sowing is common (Confalone et al., 2010).

In addition, fall sowing requires less water due to lower temperatures, and the need is met by rainfall. Nevertheless, sowing time studies have proved valuable in different parts of the world. For example, in a case where peas were sown in winter followed by wheat in areas left fallow after wheat had been sown in winter, it was observed that the winter peas had higher yields than spring sowings (Schillinger, 2017).

Peas are more sensitive to high temperatures than other legumes (Hall, 2001). The optimum germination and growth temperature of winter peas is 18-22˚C. Temperatures exceeding 25˚C during the flowering period may cause yield loss (Canavar and Kaynak, 2010; Vadez et al., 2012; Jiang et al., 2019; Lamichaney et al., 2021) and affect seed quality (Parihar et al., 2022). The period from flowering to pod formation (pod set) is the period when the pea is most sensitive to temperature (Jeuffroy et al., 2010). Studies have shown that ambient temperatures above the threshold limit will affect crop yield by causing flower and pod shedding (Guilioni et al., 2003; Bueckert et al., 2015). Studies of this issue in peas in our region are limited.

Growing degree days (GDD) are used as a tool to predict plant growth and development using temperature data (Zin et al., 2010). Temperature is the most important and the least changeable climatic factor. It influences important processes such as photosynthesis, respiration, fertilization and maturation. The concept of growth degree is based on the concept that the time required to reach a phenological stage is linearly related to temperature in the interval between the base temperature and the optimum temperature (Sreenivas et al., 2010). Predicting the growth rate and maturation times of plants is important for optimizing the timing of irrigation, fertilization and harvesting, and is one of the determinants of yield (Koca and Erekul, 2016).

In the Aegean region, with a Mediterranean climate, peas are grown as a winter crop without need for irrigation. In some years, peas are damaged by winter cold and yield losses are observed. The aim of this study was to determine the appropriate sowing time of different pea genotypes in the region by calculating growing degree days and relating them to cold damage. Due to the appropriate sowing time, higher yields are targeted in the region.

MATERIALS AND METHODS

The study was conducted in 2020/21 and 2021/22 in the experimental field (27˚51'E, 37˚51'N; altitude: 50m) of the Department of Field Crops, Faculty of Agriculture, Adnan Menderes University, Aydin/Turkey.

Table 1. Soil properties of the trial site

Soil Texture			pH	Organic Matter (%)	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Sodium (ppm)
Sand (%)	silt (%)	clay (%)						
72	16.7	11.3	8.0	2.0	21	176	2978	101
Sandy loam			High	Low	High	Low	High	Low

Source: ADU Faculty of Agriculture, Soil and Plant Nutrition Department

Data on the soil properties are given in Table 1. The soil is sandy and loamy in texture. Soil pH is high (pH=8) but organic matter content is low (2%). According to the results of the analysis, the amount of phosphorus and calcium was high while the amount of sodium and potassium was low. Soil properties are generally suitable for pea cultivation.

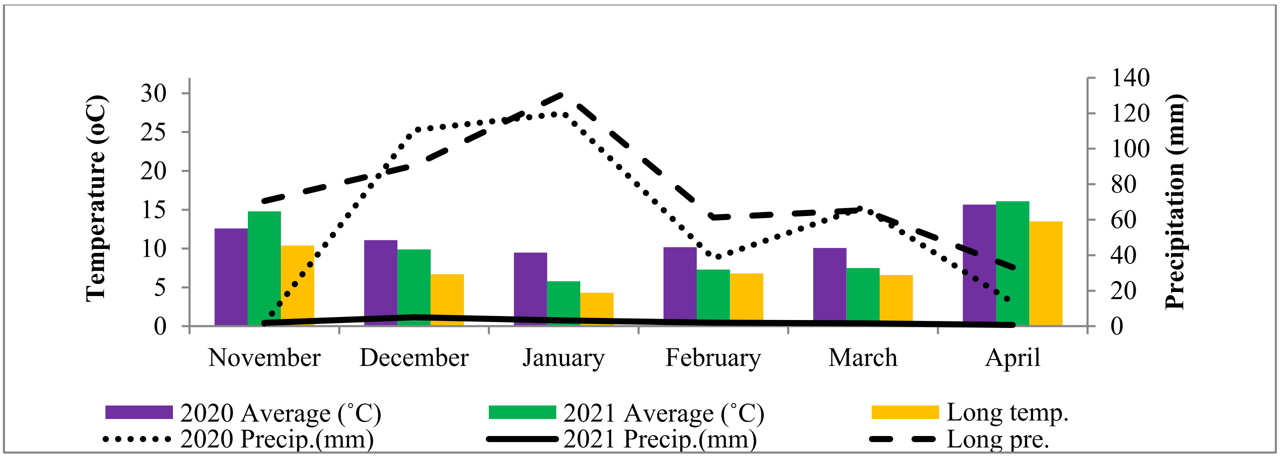

Figure 1. Climatic data of the trial site
Source: Aydin Provincial Directorate of Meteorology

Figure 1 shows the climatic data for the years of the experiment. In the first year of the study, the average air temperature was higher than the long-term average. Rainfall was irregular and exceeded the long-term average. In the second year, the average air temperature again exceeded the long-term average, but was lower than the previous year. The total amount of precipitation observed in the second year was very low.

The study investigated the dry matter values, growing degree days, seed yields and some other yield characteristics, protein yields, protein ratios and ash contents of four pea genotypes (Giresun, Mayer, Local 1, Local 2) planted on three different sowing times (November 1, November 20 and December 10). The Giresun and Mayer varieties are registered standard varieties. Local 1 and local 2 are genotypes that have been grown by the producers for many years and adapted to the Agean region. The height of the plants (cm), the numbers of branches, the numbers of pods per plant, the lengths of the pods (cm) and the numbers of seeds per pod were ascertained based on ten randomly selected plants at maturity.

All genotypes were hand-planted on the prescribed dates in two years. Irrigation was not done before sowing, soil moisture was provided by rainfall. Harvesting was carried out on April 20 for the first sowing, May 2 for the second and May 10 for the third.

The experiment was conducted in Randomized Complete Block Design (RCBD) arranged a split-plots with three replications. The experimental area was planned with sowing time as the main plot and varieties in the sub-plot. Field trial sowing was done by hand. There was no irrigation in the experiment, rainfall was utilized. Each plot had an area of 7.2m^2, and six rows 6m long and spaced 0.20 m apart were planted. Before sowing, 40kg ha-1 of nitrogen, phosphorus, and potassium were applied as 15-15-15 fertilizer. Weeding was performed by hand twice, at the beginning and end of the flowering period. Nitrogen fertilizer (20kg N ha^{-1}) was applied after sowing, when the plants reached a height of 10-15cm.

The number of seeds per pod was determined by counting the seeds in ten pods per plant. Approximately 500g of samples was dried at 60°C for 48 hours, and the weight (g) per 100 seeds was determined by counting the dry seeds and weighing four replicates of 100 seeds. Harvesting was done in an 8 m^2 area of each plot for the seed yield (t ha^{-1}).

The protein yield was calculated using the formula:

Protein yield (t ha^{-1}) = Seed Protein content (%)×Seed yield (t ha^{-1})

The seed protein content (%) and seed ash content were measured using the NIRS-FT spectrometer (German Bruker MPA) at Adnan Menderes University Agricultural Biotechnology and Food Safety Application and Research Center (ADU-TARBIYOMER) (Gislum et al., 2004).

Phenological development was observed in four periods during plant growth. The number of days and dry matter content of these periods were determined. (DAY 1: from sowing to emergence, DAY 2: from emergence to flowering, DAY 3: from flowering to pod formation, DAY 4: from pod formation to maturity). The growing degree days for these phenological periods were calculated by adding the daily average temperature above the base temperature.

GDD (Growing Degree Days) = [(Tmax + Tmin)/2] – Tbase

Tmax = Daily maximum temperature (°C)

Tmin = Daily minimum temperature (°C)

Tbase = Minimum base temperature, taken as 5˚C for pea crops (Gan et al., 2002).

The average daily temperature was used to calculate thermal time (TT) for each day (daily temperature multiplied by the number of days from emergence to physiological maturity). Cardinal temperatures – namely, base temperature (Tbase 5°C), optimum temperature (Topt), and maximum temperature (Tmax) – (Chapman et al., 1993), were assumed in the calculation of heat unit accumulation measured as growing degree days (GDD) using the equation of McMaster and Wilhelm (1997).

The fresh and dry weights (after 48 hours at 70˚C) of plants taken at the four phenological periods (DM 1: from sowing to emergence, DM 2: from emergence to flowering, DM 3: from flowering to pod formation, DM 4: from pod formation to maturity) were ascertained for dry matter calculation.

Dry matter (%) (DM) = ((Fresh weight-Dry weight)/Fresh weight)) × 100

Statistical analysis

Statistical analyses were conducted using JMP Software (version Pro 13) in the split-plot design. The experimental data for each parameter in the study were subjected to statistical analysis using the analysis of variance (ANOVA) technique, and their significance was tested by the "F" test (Gomez and Gomez, 1984). When differences were found to be significant in the ANOVA, the means were compared using Fisher's protected least significant difference (LSD) test at the $p \leq 0.05$ level.

RESULTS AND DISCUSSION

According to the analysis of variance results (Table 2), the year of sowing was found to be significant. Therefore, the average data of each year were given separately.

The mean squares for sowing time were significant for plant height, number of pods per plant, pod length, number of seeds per pod, weight per 100 seeds, biological yield, seed yield, protein yield and seed ash content. However, the genotype (cultivar) factor was found to be statistically significant for all the traits. Sowing time×cultivar interaction was statistically significant for plant height, number of branches per plant, pod length, weight per 100 seeds, seed yield, protein yield and seed protein content.

The average plant heights are presented in Table 3. Giresun variety planted at the second sowing time reached the tallest average height (38.6 cm) in 2022. Among the genotypes, the Local 1 genotype recorded the lowest height (27.1 cm) at the second sowing time in 2022. In previous studies, plant heights of 43.96-59.12 cm were measured (Dermirci and Unver, 2005). Genotype and environment jointly affect the height of the plants. The prolongation of the vegetation period by early sowing permits the plants to grow taller, but in some cases intercropping with cereals is recommended due to the high probability of lodging in peas (Urbatzka, 2010).

Table 2. ANOVA of seed yield and yield components

SV	DF	Means Square										
		Plant Height	Branches per Plant	Pods per Plant	Pod Length	Seed per Pod	100 Seed Weight	Biological Yield	Seed yield	Protein Yield	Seed protein	Seed ash
Y	1	6.463*	1.334**	51.653**	6.6646**	0.8377*	16.897**	813.33**	1479.89**	80.7875**	0.0986**	1.897**
ST	2	23.910**	0.188ns	6.709*	3.8930**	1.265**	10.8021**	4287.4**	1264.52**	121.35**	2.0909ns	0.1605*
Y × ST	2	6.878**	0.532ns	2.4093ns	0.0129ns	0.9080*	0.0011ns	1.5507ns	16.944ns	2.4190ns	1.1748ns	0.0048ns
C	3	74.547**	1.1215ns	9.8357*	3.1571**	1.8837**	6.4162**	12700.4**	5063.4**	208.636**	11.678**	3.261**
Y × C	3	0.0697ns	0.613ns	2.2208ns	0.0447ns	0.1380ns	0.003ns	0.5727ns	2.8247ns	4.0671ns	1.3050ns	0.0128ns
ST × C	6	63.466**	0.7356*	6.0770ns	4.5180**	0.9877*	5.1958**	635.01**	293.06**	20.5085**	1.8309*	0.2531ns
Y × ST×C	6	0.0539ns	0.4387ns	1.4046ns	0.0592ns	0.5261ns	0.0024ns	0.2497**	5.0058ns	4.8767ns	1.7553*	0.0327ns

**: Significant at the p≤ 0.01 level; *: Significant at the p≤ 0.05 level; ns: non-significant SV: Sources of Variation Y: years ST: Sowing time C: Cultivars

Table 3. Average plant heights measured in the study (cm)

Plant Height (cm)										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	32.4	35.7	27.4	31.8	31.8a	34.1	37.5	29.1	33.2	33.5a
2	37.4	27.4	29.3	33.4	31.9a	38.6	29.0	31.1	34.9	33.4a
3	29.8	33.0	27.7	32.4	30.7b	29.0	32.2	27.1	31.7	30.0b
Mean	33.2a	32.0a	28.2b	32.5a	31.5	33.9a	32.9a	29.1b	33.2a	32.3
CV	9.81					CV	9.26			
LSD ST	0.59					LSD ST	0.80			
LSD C	3.53					LSD C	3.42			
LSD ST×C	5.30					LSD ST×C	5.12			

ST: Sowing time C: Cultivar (1. November 1; 2. November 20; 3. December 10)

Table 4. Average number of branches per plant measured in the study

Number of Branches per Plant										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	1.00	1.33	1.33	1.00	1.17	1.00a	1.33a	1.33a	1.00a	1.17
2	2.00	2.33	1.00	1.00	1.58	1.33a	0.33b	1.33a	0.33b	0.83
3	0.33	1.67	0.67	0.67	0.83	1.00a	1.00a	0.33b	1.00a	0.83
Mean	1.11	1.78	1.00	0.89	1.19	1.11	0.89	1.00	0.78	0.94
CV	5.28					CV	4.87			
LSD ST	-					LSD ST	-			
LSD C	-					LSD C	-			
LSD ST×C	-					LSD ST×C	0.79			

ST: Sowing time C: Cultivar

The average number of branches per plant are presented in Table 4. Mayer planted at the second sowing time reached the highest average branch number (2.33) in 2021. Among the genotypes, Mayer and the Local 2 genotypes recorded the lowest number of branches (0.33 per plant) at the second sowing time in 2022. In previous studies, the mean numbers of branches were put at 1-2 and 3-4 branches per plant, but as many as 7 branches were recorded (Karayel and Bozoglu, 2008). The number of branches is affected by environmental conditions. In another study, it was found to be 5.2-7.8 pieces/plant (Ceyhan and Savur, 2010).

The average number of pods per plant are presented in Table 5. Local 2 planted at the second sowing time reached the highest average number of pods (6.67) in 2021. Among the genotypes, Giresun recorded the lowest number of pods per plant (2.52) at the third sowing time in 2022. Pod formation, which occurs within 25-30 days after flowering, is one of the main determinants of yield. Baloch et al. (1999) reported that the number of pods decreased in late sowing. Similarly, the study obtained lower pod numbers at late sowing (Haq and Ahmed, 2021).

Table 5. Average number of pods per plant measured in the study

Number of Pods per Plant										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	6.00	6.33	4.33	5.67	5.58a	4.23	4.11	3.12	3.51	3.74
2	6.52	5.33	5.83	6.67	6.09a	3.56	4.51	3.57	5.94	4.40
3	5.67	3.00	5.17	5.33	4.29b	2.52	4.94	3.19	4.86	3.88
Mean	6.02	4.89	5.11	5.89	5.36	3.44	4.52	3.29	4.77	4.00
CV	14.70					CV	9.70			
LSD ST	0.80					LSD ST	-			
LSD C	-					LSD C	-			
LSD ST×C	1.36					LSD ST×C	-			

ST: sowing time C: Cultivar

The average pod length is presented in Table 6. Giresun planted at the first sowing time reached the highest average pod length (8.00 cm) in 2021. Among the genotypes, the Mayer cultivars recorded the lowest pod length (4.24 cm) at the second sowing time in 2022. In another study on pea, the average pod length was measured 4.9-9.9 cm (Bozoglu and Karayel, 2015).

Table 6. Average pod length (cm) measured in the study

Pod Length (cm)										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	8.00	5.67	5.33	6.33	6.33a	7.28	4.97	4.57	5.54	5.59a
2	6.47	5.00	6.33	6.67	6.12a	5.71	4.24	5.59	5.91	5.36a
3	5.33	6.30	5.33	4.67	5.41b	4.59	5.55	4.57	4.34	4.76b
Mean	6.60	5.66	5.67	5.89	5.95	5.86	4.92	4.91	5.26	5.24
CV	13.06					CV	14.34			
LSD ST	0.50					LSD ST	0.43			
LSD C	-					LSD C	-			
LSD ST×C	1.39					LSD ST×C	1.30			

ST: sowing time C: Cultivar

The average numbers of seeds per pod are presented in Table 7. Giresun planted at the second sowing time reached the highest average of seeds per pod (5.40) in 2021. Among the genotypes, Local 1 genotypes recorded the lowest number of seeds per pod (3.25) at the third sowing time in 2022. The number of seeds per pod is an important indicator that affects the yield per plant. In productive cultivation, high values are desirable (Yılmaz and Kilinc, 2018).

The average 100 seed weight is presented in Table 8. Mayer variety planted at the first sowing time reached the highest average 100 seed weight (20.7 g) in 2021. Among the genotypes, the Local 2 genotype recorded the lowest 100 seed weight (15.3 g) at the third sowing time in 2022.

The average biological yield is presented in Table 9. Mayer variety planted at the second sowing time reached the highest average biological yield (298.3 kg/da) in 2021. Among the genotypes, the Local 1 and Local 2 genotype recorded the lowest biological yield (183.8 kg/da) at the third sowing time in 2022.

Table 7. Average number of seeds per pod measured in the study

Number of Seeds per Pod										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	4.60	4.06	3.66	4.33	4.16b	4.81	4.36	5.12	5.24	4.88a
2	5.30	5.40	4.67	4.16	4.88a	5.29	5.00	4.19	4.90	4.85a
3	4.50	4.06	3.33	4.53	4.11b	4.67	3.57	3.25	4.60	4.03b
Mean	4.80	4.51	3.89	4.34	4.38	4.93a	4.31a	4.19b	4.91a	4.59
CV	3.42					CV	2.93			
LSD ST	0.55					LSD ST	0.68			
LSD C	-					LSD C	0.64			
LSD ST×C	-					LSD ST×C	-			

ST: sowing time C: Cultivar

Table 8. Average 100 seed weight (g) measured in the study

100 Seed Weight (g)										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	19.7	20.7	18.3	17.3	19.0a	18.5	19.5	17.0	16.1	17.7a
2	18.7	19.3	18.7	20.0	19.2a	17.4	18.1	17.4	18.8	17.9a
3	16.7	18.3	17.7	16.5	17.3b	15.5	17.1	16.4	15.3	16.1b
Mean	18.3b	19.4a	18.2b	17.9b	18.5	17.1b	18.2a	16.9b	16.7b	17.2
CV	3.00					CV	3.23			
LSD ST	0.85					LSD ST	0.78			
LSD C	0.64					LSD C	0.57			
LSD ST×C	0.96					LSD ST×C	0.99			

ST: sowing time C: Cultivar

Table 9. Average Biological Yield (kg da^{-1}) measured in the study

Biological Yield (kg da^{-1})										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	265.0	290.3	230.0	213.3	249.7a	258.1	281.8	221.5	204.8	241.6
2	286.7	298.3	235.0	235.0	263.8a	278.1	289.8	226.5	226.4	255.2
3	267.3	248.3	193.3	193.3	225.6b	258.5	238.8	183.8	183.8	216.2
Mean	273.0a	279.0a	219.4b	213.9b	246.3	264.9	270.1	210.6	205.0	237.7
CV	3.87					CV	11.60			
LSD ST	27.5					LSD ST	-			
LSD C	22.3					LSD C	-			
LSD ST×C	33.4					LSD ST×C	-			

ST: sowing time C: Cultivar

Table 10. Average seed yield (t ha^{-1}) measured in the study

Seed Yield (t ha^{-1})										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	1.88	2.06	1.55	1.60	1.77b	1.74	1.88	1.44	1.48	1.64b
2	1.95	2.14	1.58	1.70	1.84a	1.83	2.03	1.47	1.58	1.73a
3	1.58	1.83	1.48	1.63	1.63c	1.49	1.73	1.38	1.54	1.53c
Mean	1.81b	2.01a	1.54d	1.64c	1.75	1.68b	1.88a	1.43d	1.53c	1.63
CV	3.95					CV	3.86			
LSD ST	0.029					LSD ST	0.025			
LSD C	0.063					LSD C	0.072			
LSD ST×C	0.105					LSD ST×C	0.107			

ST: sowing time C: Cultivar

The average seed yield is presented in Table 10 Mayer variety planted at the second sowing time reached the highest average seed yield (2.14 t ha^{-1}) in 2021. Among the genotypes, the Local 1 genotype recorded the lowest yield (1.38 t ha^{-1}) at the third sowing time in 2022. The local genotypes had lower yields than the standart varieties. All varieties were affected by sowing time and higher yields were obtained at the optimum second sowing time. In previous studies, the effect of sowing time on seed yield was found to be significant (Demirci and Unver, 2005; Urbatzka, 2010). In our study, it was observed that the plants planted at the first sowing time were affected by the low temperatures experienced during the winter period. Those planted at the second sowing time showed the optimum growth rate and a higher seed yield was obtained. In previous studies, it was reported that seed yield in winter sowing decreased with the delay in sowing (Ahmed et al., 2020; Kakon et al., 2020). In another study, the highest yield was obtained in early sowing (November 30) and the lowest yield was obtained in late sowing (December 30), and it was determined that the high yield was due to the high number of pods per plant and high number of seeds per pod (Ali et al., 2016). In late sowing, warm days shorten the vegetation period (Mohanty et al., 2001). In general, a decrease in yield is expected when sowing after the optimum date. In temperate climates, early sowing, even if rainfall-dependent, can result in the growth of plants that can produce a large number of pods and receive maximum sunlight for long periods (McKenzie, 1987). Researchers have also reported that early sown peas grew better and gave higher yields in a study investigating sowing time under dry conditions (Sabir and Saeed, 2013).

The average seed protein is presented in Table 11. Local 1 genotypes planted at the second sowing time reached the highest average seed protein (% 27) in 2022. Among the genotypes, Mayer variety recorded the lowest seed protein (% 23.5) at the second sowing time in 2021. In some studies, peas sown in winter have been observed to have high protein and amino acid contents (Urbatzka, 2011). In another study, pea plants were sown on three different dates (March 21, April 4 and April 18) in order to examine the effect of different sowing times on their protein content and the protein content was observed to be higher in early sowing (Caliskan et al., 2008). However, the effect of sowing time on protein yield may vary depending on regional differences and growing conditions. Therefore, the results of local studies that account for regional conditions may be more meaningful (Olle, 2017). In a study conducted in Turkey, the protein content of peas sown in March and April was higher than that of those sown in May and June (Kayacik et al., 2014). In similar studies, it was determined that peas sown early gave higher yields and higher quality seeds (Jost and Erban, 2017; Zhu et al., 2018). There is a positive correlation between days to maturity and seed protein content in peas, but the reduction of this period in regions with a warmer climate is a disadvantage (Hacısalihoglu et al., 2020). In our study, similarly, high protein rate (26.6%) was obtained in Giresun due to the long maturity period.

The average protein yield is presented in Table 12. Giresun variety planted at the first sowing time reached the highest protein yield (51.9 t ha^{-1}) in 2021. Among the genotypes, the Local 1 genotype recorded the lowest protein yield (34.7 t ha^{-1}) at the third sowing time in 2022.

Table 11. Average seed protein (%) measured in the study

Seed Protein (%)										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	24.7	23.7	24.7	23.7	24.2	26.6	24.1	25.3	24.1	25.0
2	26.7	23.5	26.5	25.0	25.4	25.1	23.7	27.0	25.2	25.3
3	25.5	24.2	24.2	23.7	24.4	25.2	24.6	25.2	25.0	25.0
Mean	25.6a	23.8b	25.1a	24.1b	24.7	25.6a	24.1b	25.8a	24.8b	25.1
CV	0.13					CV	3.35			
LSD ST	-					LSD ST	-			
LSD C	0.94					LSD C	0.97			
LSD ST×C	-					LSD ST×C	1.46			

ST: sowing time C: Cultivar

Table 12. Average protein yield (t ha^{-1}) in the study

Protein Yield (t ha^{-1})										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	46.6	48.8	38.2	37.9	42.9b	46.3	45.4	36.4	35.7	40.9b
2	51.9	50.4	42.0	42.5	46.7a	46.0	48.1	39.6	39.9	43.4a
3	40.5	44.1	35.8	38.7	39.8c	37.4	42.5	34.7	38.4	38.3c
Mean	46.3a	47.8a	38.7b	39.7b	43.1	43.2b	45.3a	36.9c	38.0c	40.9
CV	0.047					CV	0.067			
LSD ST	2.40					LSD ST	1.17			
LSD C	2.31					LSD C	2.18			
LSD ST×C	-					LSD ST×C	3.28			

ST: sowing time C: Cultivar

Table 13. Average seed ash (%) measured in the study

Seed Ash (%)										
Sowing Time	2021				Mean	2022				Mean
	Giresun	Mayer	Local 1	Local 2		Giresun	Mayer	Local 1	Local 2	
1	6.77	6.94	5.77	5.63	6.28	6.36	6.53	5.36	5.22	5.87
2	6.73	6.83	6.03	5.77	6.34	6.33	6.45	5.65	5.39	5.96
3	6.50	6.60	6.23	5.37	6.18	6.06	6.13	5.76	4.90	5.71
Mean	6.67a	6.79a	6.01b	5.59c	6.26	6.25a	6.37a	5.59b	5.17b	5.85
CV		0.06			CV		0.07			
LSD ST		-			LSD ST		-			
LSD C		0.483			LSD C		0.552			
LSD ST×C		-			LSD ST×C		-			

ST: sowing time C: Cultivar

Table 14. ANOVA for phenological observations in the study

SV	DF	Means of Square											
		DAY1	GDD1	DM1	DAY2	GDD2	DM2	DAY3	GDD3	DM3	DAY4	GDD4	DM4
Y	1	66.13**	203.11 ns	130.5*	1156.3**	6190.1**	85492.5*	246.05**	8042.7**	6283.1ns	4.253ns	4609.7**	9135.0ns
ST	2	56.01**	8539.4**	5156.6**	92.82**	70331.1*	77382**	13116**	435.09**	63558.6*	6361.1**	32936.4*	31371.3*
Y×ST	2	0.125ns	2275.8**	232.3**	16.71**	58208.8*	122.8ns	0.421ns	2470.4**	2.778ns	542.42**	19084.9*	312.04ns
C	3	22.05**	2016.7**	143.8*	2828.2**	103047**	62545.7*	975.7**	16378.5*	9908.1**	163.5**	7195.4**	30079.3*
Y×C	3	2.791**	264.4**	38.2ns	100.4**	16181.8*	29.68ns	0.987ns	1066.7**	60.19ns	166.9**	12678.3*	0.680ns
ST×C	6	20.27**	2056.7**	63.2ns	58.23**	1300.4**	5583.7**	253.30**	1830.2**	31771.3*	222.13**	15463.4*	3592.8*
Y×ST×C	6	1.902**	180.21**	45.9ns	52.13**	1407.1**	112.4ns	0.231ns	5613.1**	116.32ns	66.559**	3482.4**	0.6805ns

**: Significant at the $p \leq 0.01$ level; *: Significant at the $p \leq 0.05$ level; ns: non-significant

SV: Sources of Variation, Y: years, ST: Sowing time, C: Cultivars, DAY: The number of days, DM:Dry matter, Phenological periods: 1: sowing-emergence; 2: emergence-flowering; 3: flowering-pod formation;4:pod formation-maturity

Table 15. Phenological traits in the first year of the study (2020-2021)

ST	C	Phenological Periods											
		DAY1	GDD1	DM1	DAY2	GDD2	DM2	DAY3	GDD3	DM3	DAY4	GDD4	DM4
1 (Nov 1)	Giresun	10.3	110.6	119.3	53.0	433.4	560.4	91.3	674.1	970.8	165.3	1469.2	1651.2
	Mayer	7.3	77.1	115.4	27.7	248.4	455.5	83.3	624.0	698.1	150.3	1325.5	1229.9
	Local 1	11.3	120.5	121.7	53.7	437.1	525.2	92.3	683.4	887.2	154.0	1359.3	1532.4
	Local 2	5.0	47.3	113.8	30.7	271.6	489.1	83.3	624.0	805.5	158.0	1401.0	1414.6
	Mean	8.5	88.9	117.6	41.3	347.6	507.5	87.6	651.4	840.4	156.9	1388.7	1457.0
2 (Nov 20)	Giresun	13.7	103.0	119.2	55.7	419.3	681.8	120.3	999.4	976.9	134.7	1347.1	1778.6
	Mayer	11.7	89.2	111.0	30.7	234.5	527.3	114.7	912.3	863.7	134.3	1340.6	1511.0
	Local 1	10.0	75.6	119.1	56.7	423.2	575.1	117.7	949.3	927.5	135.3	1359.1	1622.5
	Local 2	9.7	77.8	111.5	33.3	246.7	466.7	113.3	891.2	783.9	134.7	1346.9	1503.9
	Mean	11.3	86.4	115.2	44.1	330.9	562.7	116.5	938.0	888.0	134.8	1348.4	1604.0
3 (Dec 10)	Giresun	8.7	73.4	136.5	57.7	425.9	678.9	82.5	555.9	1041.9	113.7	1160.9	1840.8
	Mayer	5.7	53.1	137.0	31.7	239.4	586.4	56.5	548.3	989.6	112.7	1142.4	1662.8
	Local 1	9.7	78.6	138.2	59.2	429.0	633.9	84.0	585.3	856.3	121.7	1304.8	1610.1
	Local 2	10.5	82.5	139.5	34.5	252.0	577.1	59.3	616.6	872.1	117.5	1230.0	1569.2
	Mean	8.6	71.9	137.8	45.8	336.6	619.1	70.6	576.5	940.0	116.4	1209.5	1670.7

ST:sowing time, C: Cultivars, DAY: The number of days, DM:Dry matter, phenological periods: 1:sowing-emergence; 2:emergence-flowering;3:flowering-pod formation;4:pod formation-maturity

Table 16. Phenological traits in the second year of the study (2021-2022)

ST	C	Phenological Periods											
		DAY1	GDD1	DM1	DAY2	GDD2	DM2	DAY3	GDD3	DM3	DAY4	GDD4	DM4
1 (Nov 1)	Giresun	8.3	115.5	112.2	60.0	509.2	632.4	94.7	658.9	993.8	159.8	1053.6	1621.2
	Mayer	5.0	71.0	104.0	40.0	402.7	520.2	87.0	627.5	721.1	144.8	932.7	1199.9
	Local 1	8.3	115.5	112.1	60.7	514.0	597.2	95.3	662.1	891.3	124.7	825.5	1502.4
	Local 2	5.3	76.0	104.5	37.7	385.3	561.1	87.7	629.5	828.5	152.5	975.7	1384.6
	Mean	6.8	94.5	108.2	49.6	452.8	577.7	91.2	644.5	858.7	145.5	946.9	1427.0
2 (Nov 20)	Giresun	10.3	107.7	106.3	54.3	387.2	740.4	125.0	555.3	981.0	140.3	824.5	1756.6
	Mayer	9.3	98.9	105.9	56.0	392.2	579.2	119.0	515.1	886.7	141.0	829.5	1489.0
	Local 1	7.7	76.7	123.1	63.7	407.2	647.1	120.7	524.0	950.5	141.7	835.7	1600.5
	Local 2	9.7	102.5	118.7	40.3	293.3	539.7	117.3	507.1	806.9	137.3	789.4	1481.9
	Mean	9.3	96.4	113.5	53.6	370.0	626.6	120.5	525.4	906.3	140.1	819.8	1582.0
3 (Dec 10)	Giresun	6.7	47.0	139.2	64.7	288.3	750.9	86.3	425.8	1059.1	123.3	677.0	1823.5
	Mayer	4.3	37.2	140.2	38.7	206.6	668.4	60.0	288.2	1004.3	124.3	680.7	1647.8
	Local 1	7.7	49.8	140.4	63.0	281.9	705.9	87.0	428.3	879.3	117.3	639.9	1595.1
	Local 2	7.7	50.1	142.1	41.3	214.2	644.5	62.8	301.3	905.7	119.3	652.9	1567.4
	Mean	6.6	46.0	140.5	51.9	247.7	692.4	74.0	360.9	962.1	121.1	662.6	1658.4

ST: sowing time, C: Cultivars, DAY: The number of days, DM:Dry matter, phenological periods: 1:sowing-emergence; 2:emergence-flowering;3:flowering-pod formation;4:pod formation-maturity

The average seed ash is presented in Table 13. Mayer variety planted at the first sowing time reached the highest average seed ash (% 6.94) in 2021. Among the genotypes, the Local 2 genotype recorded the lowest seed ash (% 4.90) at the third sowing time in 2022. Wang et al (2010) found average ash values of 8.9-9.0%. In another study, Nikolopoulou et al. (2007) measured values in the range of 3.05-4.06%. The results of the study are consistent with Costa et al. (2006) and Petterson et al. (1997).

Table 14 presents the analysis of variance table for phenological traits. Since the year of sowing was found to be significant for these traits, the averages were presented separately for each year. The effects of sowing time, variety and sowing time*variety interaction on these traits were all found to be statistically significant.

GDD is a trait used to predict the developmental periods of plants. As shown in Tables 15 and 16, the number of days to emergence for peas sown at the second sowing time (November 20) is longer than for the other sowing times due to low temperatures. For example, in the first year of the study, the mean emergence period for the second sowing time was 11.3 days compared to 8.6 days for the third sowing time (8.6 days). These results were consistent with Gan et al. (2002). Regarding the period from pod set to maturation, it was observed that the latest-sown plants matured in the shortest period (116. 4 days in the first year of the study). Early sowing is a method that allows plants to escape from the stress of high evapotranspiration in late maturing plants and research has shown that there are yield advantages with early sowing (Miller, 2000).

In previous studies, grain setting decreased by 7-14% at high temperatures (Lamichaney et al., 2021). It has also been observed that early pea sowings (December 1) had higher GDD values than late sowings (December 15) in all cultivars, and that the time from pod formation to maturity decreased with the delay in sowing due to the higher temperature (Devi et al., 2019). In another study, the high temperature effect was observed to be significant and pronounced in pea cultivation, and GDD was calculated to be between 732 ^{0}C and 281 ^{0}C during the flowering period while GDD measured during the vegetative period was not significant (Parihar et al., 2022). Lamichaney et al. (2021) stated that providing favorable temperature conditions for plant growth among genotypes can improve plant productivity. In conclusion, Growing Degree Days (GDD) is an important tool used to monitor, predict and optimize plant growth. Plant breeders and agronomists can plan and manage their farming activities better using GDD data.

CONCLUSION

The results of this study showed that the values of seed yield and yield components obtained from pea plants sown at the second sowing time were higher (1.84 t ha^{-1} for seed yield in the first year of the study) than from those sown at the other sowing times. The seed yield of plants sown at the second sowing time was less affected by the winter period than that of plants sown at the first sowing time. Cold periods stopped the growth of the plant. The long vegetation period in fall sowing results in a good development period and high biomass formation. These factors resulted in higher biological yields (263.8kg/ha and 255.2kg/ha) at the second sowing time in both years of the study. The sowing time also had a significant effect on the seed protein ratio and protein yield, and the second sowing time gave the best results in each case. Standard varieties performed better than local varieties in terms of the seed yield and the seed protein ratio. When phenological traits were analyzed, the vegetation period was longest for the first sowing time, followed by the second sowing time and then the third sowing time. However, the highest dry matter content was obtained from the third sowing time, followed by the second sowing time and then the first sowing time. The high amount of rainfall observed in the first year prolonged the flowering and pod setting periods for plants sown at the second sowing time. In the second year, low rainfall and average temperature values above the historic average shortened the vegetation period. The highest dry matter content for all varieties was observed in plans sown at the third sowing time. Among the varieties, although the Mayer variety completed the phenological periods in a shorter time than the others, it accumulated lower levels of GDD requirement and dry matter, and this accumulation was manifested in the seed yield. On the other hand, the Giresun variety accumulated higher GDD and more dry matter. However, this accumulation is manifested in the biological yield. In the local cultivars, the later the sowing, the shorter the vegetation period and the less dry matter accumulation was observed, although lower GDD values were obtained. As a result, sowing times for standard or local genotypes can be planned in the light of the information obtained from the study.

LITERATURE CITED

Ali, M. Z., M.A. Aziz, M.A.I. Sarker, S. Mazumder, S.K. Paul, T.A. Mujahidi and M.S. Bhuiyan. 2016. Effect of sowing time based temperature variations on growth, yield and seed quality of garden pea. Bangladesh Agronomy Journal 19(1):29-36.

Ahmed, B., A.K. Hasan, B. Karmakar, M. Hasan, F. Akter, P.S. Saha and M. Haq. 2020. Influence of date of sowing on growth and yield performance of field pea (*Pisum sativum* L.) genotypes. Asian Research Journal of Agriculture 13(2): 26-34.

Baloch, A. F., S.M. Qayyum, A.A. Kakar and M.A. Baloch. 1999. Marketable green pod yield response of two pea varieties to different sowing dates. Sarhad Journal of Agriculture 15(2): 83-86. Pakistan.

Karayel, R. and H. Bozoglu. 2015. Determination of morphological variability of local pea genotypes. Ekin Journal of Crop Breeding and Genetics, 1(2): 56-64.

Bueckert, R.A., S. Wagenhoffer, G. Hnatowich and T.D. Warkentin. 2015. Effect of heat and precipitation on pea yield and reproductive performance in the field. Canadian Journal of Plant Science 95(4): 629-639.

Caliskan, S., M.E. Caliskan, M. Arslan and H. Arioglu. 2008. Effects of sowing date and growth duration on growth and yield of groundnut in a Mediterranean-type environment in Turkey. Field Crops Research 105(1-2): 131-140.

Canavar, O. and M. Kaynak. 2010. Growing degree day and sunshine radiation effects on peanut pod yield and growth. African Journal of Biotechnology 9(15): 2234-2241.

Ceyhan, O. and E. Savur. 2011. Determination of some agronomic characteristics of edible pea (Pisum sativum L.) lines obtained by hybridization method. Selcuk Uni. Selcuk Journal of Agricultural and Food Sciences 25 (2): 17-23.

Change, C. 2007. IPCC fourth assessment report. The physical science basis, 2: 580-595.

Chapman, S.C., G.L. Hammer and J.A. Palta. 1993. Predicting leaf area development of sunflower. Field Crops Research 34(1): 101-112.

Costa, G. E., K.S. Queiroz-Monici, S.M. Reis and A.C. Oliviera. 2006. Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. Food Chemistry 94: 327–330.

Confalone, A.J.I. Lizaso, B. Ruiz-Nogueira, F.X. López-Cedrón and F. Sau. 2010. Growth, PAR use efficiency, and yield components of field-grown Vicia faba L. under different temperature and photoperiod regimes. Field Crops Research 115(2): 140–148.

Demirci, G. and S. Unver. 2005. Effects of different sowing times on yield and yield components of pea (*Pisum sativum* L.) under Ankara conditions. Anadolu J. of AARI. 15 (1): 49-60.

Devi, S., M. Singh and R.K. Aggarwal. 2019. Thermal requirements and heat use efficiency of pea cultivars under varying environments. Current World Environment 14(3): 376.

Doring, T.F. and M. Reckling. 2018. Detecting global trends of cereal yield stability by adjusting the coefficient of variation. Eur. J. Agron. 99: 30–36.

Esser-Monning, K., P. Roskothen and G. Robbelen. 1995. Two host genes in Vicia faba for nodulation deficiency with strain specifity for Rhizobium leguminosarum. Plant Bred. 114: 363–365.

FAO, 2021. www.fao.org. https://www.fao.org/faostat/en/#data/QCL (Access date: 12.10.2023)

Flores, F., S. Nadal, I. Solis, J. Winkler, O. Sass, F.L. Stoddard, W. Link, B. Raffiot, F. Muel and D. Rubiales. 2012. Faba bean adaptation to autumn sowing under European climates. Agron. Sustain. Dev. 32: 727–734.

Gan, Y.T., P.R. Miller, P.H. Liu, F.C. Stevenson and C.L. McDonald. 2002. Seedling emergence, pod development, and seed yields of chickpea and dry pea in a semiarid environment. Canadian Journal of Plant Science 82(3): 531-537.

Gislum, R., E. Micklander and J.P. Nielsen. 2004. Quantification of nitrogen concentration in perennial ryegrass and red fescue using near-infrared reflectance spectroscopy (NIRS) and chemometrics. Field Crops Research 88(2-3): 269-277.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. John Wiley & Sons.

Guilioni, L., J. Wéry and J. Lecoeur. 2003. High temperature and water deficit may reduce seed number in field pea purely by decreasing plant growth rate. Funct Plant Biol. 30:1151–1164.

Hacisalihoglu, G., J. Freeman, P.R. Armstrong, B.W. Seabourn, L.D. Porter, A.M. Settles. 2020. Protein, weight, and oil prediction by single-seed near-infrared spectroscopy for selection of seed quality and yield traits in pea (Pisum sativum). Journal of the Science of Food and Agriculture 100(8):3488-3497.

Haq, M.T. and M.S. Ahmed. 2021. Effect of sowing date on growth and yield performance of pea (Pisum sativum L.). Journal of Elt and Education 4(4): 75-79.

Hall, A.E. 2001. Crop responses to environment. (CRC Press: Boca Raton, FL)

Jeufroy, M.H., J. Lecoeur and R. Roche. 2010. The seed number. In ‘Physiology of the pea crop’. (Eds N Munier-Jolain, V Biarnès, I Chaillet, J Lecoeur, MH Jeufroy) pp. 104–131. (CRC Press: Enfeld, NH)

Jiang, Y., A.R. Davis, V. Vujanovic and R.A. Bueckert. 2019. Reproductive development response to high daytime temperature in feld pea. J Agron Crop Sci. 205:324–333.

Jost, R., and A. Erban. 2017. The influence of sowing date on the yield and quality of pea (Pisum sativum L.) seeds. Agricultural and Food Science 26(4): 220-229.

Kakon, S.S., M.M. Sheikh, M.S.A. Khan, A.A. Begum, J.A. Chowdhury and M.A. Hossain. 2020. Sowing time and management effects on phenology, growth and yield of garden pea. Bangladesh Agronomy Journal 23(2): 13-22.

Karayel, R. and H. Bozoglu. 2008. Some agronomic characteristics of local pea populations collected from different regions of Turkey. Anatolian Journal of Agricultural Sciences 23(1): 32-38.

Kayacık, H., A. Inal, M. Demirci and K. Gunduz. 2014. The Effect of Different Sowing Times on Some Characteristics of Pea (Pisum sativum L.) Plant. Journal of Uludag University Faculty of Agriculture 28(2): 39-47.

Koca Y.O. and O. Erekul. 2016. Changes of dry matter, biomass ad relative growth rate with different phenological stages of corn. Agriculture and Agricultural Science Procedia 10. 5th International Conference Agriculture for Life, Life for Agriculture: 67 – 75.

Lamichaney, A., A.K. Parihar, K.K. Hazra, G.P. Dixit, P.K. Katiyar, D. Singh, A.K. Singh, N. Kumar and N.P. Singh. 2021. Untangling the influence of heat stress on crop phenology, seed set, seed weight, and germination in field pea (Pisum sativum L.). Front Pla Sci. 12:437

Van Kessel, C. and C. Hartley. 2000. Agricultural management of grain legumes: Has it led to an increase in nitrogen fixation? Field Crops Res. 65: 165–181.

McDonald, G.K. and D. Peck. 2009. Effects of crop rotation, residue retention and sowing time on the incidence and survival of ascochyta blight and its effect on grain yield of field peas (*Pisum sativum* L.). Field Crops Res. 111:11-21.

McKenzie, B.A. 1987. The growth development and water use of lentils (Lens culinaris Medik). Unpublished PhD thesis, Lincoln College, University of Canterbury: New Zealand.

McMaster, G. S. and W.W. Wilhelm. 1997. Growing degree-days: one equation, two interpretations. Agricultural and Forest Meteorology 87(4): 291-300.

Miller, P.R., C.L. McDonald, D.A. Derksen and J. Waddington. 2000. The adaptation of seven broadleaf crops to the dry semiarid prairie. Can. J. Plant Sci. 81: 29–43.

Mohanty, S.K., B. Baisakih, U.K. Dikshit and B. Bhol. 2001. Kalamung, a promising localmungbean cultivar. Environ. Ecol. 16(1): 222-223.

Neugschwandtner, R.W., A. Bernhuber, S. Kammlander, H. Wagentristl, A. Klimek-Kopyra and H.P. Kaul. 2020. Yield structure components of autumn- and spring-sown pea (*Pisum sativum* L.). Acta Agric. Scand. B Soil Plant Sci. 70: 109–116.

Nicolas Tremblay, E.F. and Y. Desjardins. 2006. Relationships among growing degree-days, tenderness, other harvest attributes and market value of processing pea (*Pisum sativum* L.) cultivars grown in Quebec. Canadian Journal of Plant Science 86(2): 525-537.

Nikolopoulou, D., K. Grigorakis, M. Stasini, M.N. Alexis and K. Iliadis. 2007. Differences in chemical composition of field pea (Pisum sativum) cultivars: Effect of cultivation area and year. Food Chemistry 103: 847–852.

Olle, M. 2017. The effect of sowing rate and variety on the yield, protein content and height of field pea. International Journal of Food and Biosystems Engineering 3(1): 11-18.

Parihar, A.K., K.K. Hazra, A. Lamichaney, G.P. Dixit, D. Singh, A.K. Singh and N.P. Singh. 2022. Characterizing plant trait (s) for improved heat tolerance in field pea (Pisum sativum L.) under subtropical climate. International Journal of Biometeorology 66(6): 1267-1281.

Petterson, D., S. Sipsas and J.B. Mackintosh. 1997. The chemical composition and nutritive value of Australian pulses. Canberra, Australia: Grains Research and Development Corporation.

Rubiales, D., M. Fernández-Aparicio, A. Moral, E. Barilli, J.C. Sillero and S. Fondevilla. 2009. Disease resistance in pea (Pisum sativum L.) types for autumn sowings in Mediterranean environments. Czech J Genet Plant. 45:135–142.

Sabir, M. and M. Saeed. 2013. Effect of planting date on the growth and yield of pea (Pisum sativum L.) under arid environment. Sarhad Journal of Agriculture 29(1): 57-63.

Schillinger, F.W. 2017. Winter Pea: Promising new crop for Washington's dryland wheat-fallow region. Frontiers in Ecology and Evolution 5: 43.

Silim, S.N., P.D. Hebblethwaite and M.C. Heath. 1985. Comparison of the effects of autumn and spring sowing date on growth and yield of combining peas (*Pisum sativum* L.). The Journal of Agricultural Science 104(1): 35-46.

Srivastava, B.K. 1991. Morpho-physiological response of garden pea (*Pisum sativum* L.) cultivars to sowing dates. IV: Yield and yield components. Research and Development Reporter 8 (2): 137-143.

Smytkiewicz, K., J. Podleśny, J. Wielbo and A. Podleśna. 2021. The effect of a preparation containing rhizobial Nod factors on pea morphological traits and physiology. Agronomy 11(8): 1457.

Sreenivas, G., M.D. Reddy and D.R. Reddy. 2010. Agrometeorological indices in relation to phenology of aerobic rice. Journal of Agrometerology 12: 241-244.

Tulbek, M.C. 2014. Pulse flours as functional ingredients. In: IUFOST annual conference, Montreal QC, Canada.

Tulbek, M.C., R.S.H. Lam, P. Asavajaru and A. Lam. 2017. Pea: A sustainable vegetable protein crop. In Sustainable protein sources: 145-164. Academic Press. https://doi.org/10.1016/B978-0-12-802778-3.00009-3

Urbatzka, P. 2010. Anbauwurdigkeit von Wintererbsen-ein Vergleich zu Sommererbsen in Rein-und Gemengesaat unter den Bedingungen des okologischen Landbaus. PhD Thesis. Universität Kassel, Fachgebiet Okologischer Land- und Pflanzenbau. Hamburg/GERMANY.

Vadez, V., J.D. Berger, T. Warkentin, S. Asseng, P. Ratnakumar, K.P.C. Rao, P.M. Gaur, J.N. Munier, A. Larmure, A.S. Voisin and H.C. Sharma. 2012. Adaptation of grain legumes to climate change: a review. Agron Sustain Dev 32:31–44.

Wang, N., D.W. Hatcher, T.D. Warkentin and R. Toews. 2010. Effect of cultivar and environment on physicochemical and cooking characteristics of field pea (*Pisum sativum*). Food chemistry 118(1): 109-115.

Yilmaz, N. and H.V. Kilinc. 2018. Determination of yield and yield components of local pea (Pisum sativum L.) populations grown in Giresun province. Academic Journal of Agriculture 7(2): 163-172.

Zboi ´nska, M. 2018. How plants uptake and assimilate nitrogen? Eduk. Biol. I Sr. 2: 19–31

Zhu, Y., L. Li and X. Xu. 2018. Effects of sowing time on growth and yield of spring pea (Pisum sativum L.) in central China. Acta Agronomica Sinica 44(1): 28-36

Zinn, K.K., M. Tunc-Ozdemir and J.F. Harper. 2010. Temperature stress and plant sexual reproduction: uncovering the weakest links. Journal of Environmental and Experimental Botany 61: 1959-1968.