EFFECT OF SOME PLANT GROWTH REGULATORS WITH RETARDING ACTIVITY ON SPRING PEA FOR GRAIN

ЕФЕКТ НА НЯКОИ РАСТЕЖНИ РЕГУЛАТОРИ С РЕТАРДАНТНА АКТИВНОСТ ПРИ ПРОЛЕТЕН ГРАХ ЗА ЗЪРНО

Tsenka ZHELYAZKOVA, Maria GERDZHIKOVA and Dimitar PAVLOV

Department of Plant Growing, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria, e-mail: tsenka@abv.bg Tel/Fax: +359 42 670 942 *correspondence

ABSTRACT

A field experiment was conducted at Trakia University - Stara Zagora to establish the effect of some growth retardants on morphological and productive parameters in spring pea for grain variety Bogatir. Three combined preparations: Trisalvit (phenylphthalamic acid + chlorocholine chloride + chlorophenoxyacetic acid +salicylic acid) at doses of 300 and 400 cm^3*ha^{-1}; SM-21 (phenylphthalamic acid + chlorocholine chloride) at doses of 300 and 400 cm^3*ha^{-1} and PNSA-44 (phenylphthalamic acid + naphthaleneacetic acid + chlorophenoxyacetic acid) at doses of 200 and 300 cm^3*ha^{-1} were applied in the early growth phase of the plant up to a height of 15-20 cm. The study showed that the greatest reduction in the stem height (by 12.8% compared to untreated plants) was achieved by applying SM-21 (400 cm^3*ha^{-1}). The application of growth regulators Trisalvit and SM-21 had no appreciable effect on the production of spring pea grain. Maximum values of yield structure components (number of pods and grain per plant, grain mass per plant and mass of 1000 grain) and the yield were obtained after application of PNSA-44 (300 cm^3*ha^{-1}) - up to 5.6% (117.2 $kg*ha^{-1}$) more grain than the control. The investigation of the influence of tested factors (retardant, dose and year) demonstrated that the conditions of the year as a factor had the strongest effect on plant height and grain yield.

Key Word: spring pea, retardants, height of the stem, yield structure elements, productivity

РЕЗЮМЕ

В Тракийски университет – гр. Стара Загора е проведен полски опит за установяване ефекта на някои растежни регулатори върху морфологичните и продуктивни показатели при пролетен грах за зърно сорт Богатир. Комбинираните препарати: Трисалвит (фенилфталаминова киселина +

хлорхолинхлорид + феноксиоцетна киселина + салицилова киселина) в дози 300 и 400 с cm^3*ha^{-1}; СМ–21 (фенилфталаминова киселина + хлорхолинхлорид) в дози 300 и 400 с cm^3*ha^{-1} и ПНСА–44 (фенилфталаминова киселина + нафтилоцетна киселина + хлорфеноксиоцетна киселина) в дози 200 и 300 cm^3*ha^{-1} са приложени във фаза отрастване на растенията (15 - 20 cm височина).

В резултат на проучването е установено, че най-голямо намаление на височината на стъблото (с 12.76% спрямо нетретираните растения) се постига при прилагане на препарата СМ-21 - 400 cm^3*ha^{-1}). Приложението на растежните регулатори Трисалвит и СМ-21 не влияе съществено върху продуктивността на зърно от пролетен грах. Увеличение на структурните елементи на добива (брой бобове и семена от едно растение, маса на семената от едно растение и маса на 1000 семена) както и на стопанския добив се получава от препарата ПНСА-44 (300 cm^3*ha^{-1}) – до 5.63% (117.2 $kg*ha^{-1}$) повече зърно. Изследването за установяване влиянието на изпитваните фактори (ретардант, доза и година) показва, че най-силно влияние върху височината на растенията и добива на зърно оказват условията на годината.

Ключови думи: пролетен грах, растежни ретарданти, височина на стъблото, продуктивност, структурни елементи на добива

РАЗШИРЕНО РЕЗЮМЕ

През 2007 - 2008 г. на учебно-експерименталната база на катедра “Растениевъдство” при Тракийски университет – гр.Стара Загора е изведен полски опит за установяване ефекта на някои растежни регулатори с ретардантна активност върху морфологичните и продуктивни показатели при пролетен грах за зърно сорт Богатир. Опитът е заложен по блоковия метод, в 4 повторения, с големина на реколтната парцела 10 m^2.

Комбинираните препарати: Трисалвит (производни на фенилфталаминовата киселина, хлорхолинхлорид, производни на феноксиоцетната киселина, салицилова киселина и микроелементи) в дози 300 и 400 cm^3*ha^{-1}; СМ–21 (производни на фенилфталаминовата киселина, хлорхолинхлорид и микроелементи) в дози 300 и 400 cm^3*ha^{-1} и ПНСА–44 (производни на фенилфталаминовата киселина, производни на нафтилоцетната и хлорфеноксиоцетната киселина и микроелементи) в дози 200 и 300 cm^3*ha^{-1} са приложени във фаза отрастване на растенията (15 - 20 cm височина).

Третирането с изпитваните растежни регулатори с ретардантна активност оказва влияние върху височината на стъблото като резултатите показват, че всички приложени препарати и дози водят до нейното намаление. Най-голямо е намалението при третиране с препарата СМ-21 (400 cm^3*ha^{-1}), където разликата с нетретирания вариант е 9.0 cm (12.8 %) и е статистически много добре доказана ($P< 0.001$).

Приложението на растежните регулатори Трисалвит и СМ-21 не влияе съществено върху продуктивността на зърно от пролетен грах. Увеличение на добива на зърно се получава от препарата ПНСА-44 (300 cm^3*ha^{-1}) – до 5.6% (117.2 $kg*ha^{-1}$) повече зърно.

Изпитваните растежни регулатори с ретардантна активност не довеждат до структурни аномалии и растенията се развиват напълно нормално. Третирането с препаратите Трисалвит и СМ-21 не оказва съществено влияние върху стойностите на структурните елементи на добива. Нарастване на броя на бобовете и семената от растение и масата на семената от растение се получава при третиране с препарата ПНСА-44. При по-високата приложена доза от този препарат (300 cm^3*ha^{-1}) нарастването е съответно средно с 3.6%; 5.6% и 4.6% спрямо контролата.

Изследването за установяване влиянието на изпитваните фактори (ретардант, доза и година) показва, че най-силно влияние върху височината на растенията и добива на зърно оказват условията на годината.

Силата на влияние на вида на ретарданта върху тези показатели е много добре доказана, но значително по-ниска. Не съществува доказано взаимодействие между ретардантите и дозата на приложението им, между дозата и годината, както и между вида на ретарданта, дозата и годината върху върху височината на растенията и добива на зърно.

Добивът на зърно от пролетен грах е в добра корелационна зависимост с количеството на вегетационните валежи. Разработените на тази база регресионни зависимости позволяват да се извършва предварителна оценка на продуктивността със задоволителна за практически цели точност.

INTRODUCTION

Producing enough protein of high biological value in animal nutrition is very important for achieving high production efficiency of animal husbandry. To ensure protein balanced rations for animals, high quality plant proteins should be produced. One quick way to increase the protein supply in animal feeds is the cultivation of annual beans for grain production. Spring pea (*Pisum sativum* L.) is an important source of grain for solving the protein problem in the dry conditions of Bulgaria. Despite the optimization of the main elements of the cultivation technology of this plant, the biological potential for grain yield is not achieved yet. Existing tall pea varieties are highly prone to lie down. The lying down in the period of pod forming leads to reduction of leaf area, the content of chlorophyll and photosynthetic activity of chloroplasts, which ultimately results in reduced yields of pea grain and fodder with deteriorated quality (Amelin, 1997 a, 1997b; Kertikov, 1999; Elkoca and Kantar, 2006).

One possibility for reducing the degree of lying down of pea is creating mixed crops with annual cereals as companion plant. The use of annual cereals as supporting plants helps to reduce losses of grain, but the biological yield of pea decreases proportionally to increasing the share of the cereal component in seeding rate (Kertikov, 1998, 1999).

Another possibility for reducing lying down of pea is the application of growth regulators. According to many authors, auxins and gibberellins control separate processes, which together contribute to the elongation of pea stems. The deficiency in any of them reduces the elongation of stem cells and leads to the formation of branched, dense phenotype pea with lower stalks (Haga and Iino, 1998; Symons et

al., 1999; Yang et al. 1993, 1996). Inhibitors transporting auxins - 2, 3, 5- triiodinated benzoic acid, 9-hydroxy fluoro-9-carboxylic acid and 1-N- naphthylphthalamic acid, applied to internodes in peas significantly reduce the level of endogenic gibberellins under applications section (Ross et al., 1995; Ross, 1998). Gibberellins synthesis in peas could be also suppressed by some retardants as paklobutrazol, leading to a reduced length of stems (Hamid and Williams, 1997).

The investigations of Sanghavi et al. (1980), Chandra et al. (1989), Bora and Sarma (2003, 2006), Elkoca and Kantar (2006) show that the spraying of peas plants during the vegetation with chlorocholine chloride (CCC, Chlormequat, Cikocel) leads to reduced height, increased stem thickness and reduced tendency to lying down. A positive effect on increasing of germination of seed during storage and germination of seeds on the field (Kanp et al., 2009), the contents of chlorophyll (Bora and Sarma, 2003, 2006; Kanp et al., 2009), the mass of 1000 seeds and harvest index (Chandra et al., 1989) and increase the yield of seeds (Elkoca and Kantar, 2006) was established by treatment with chlorocholine chloride.

In Bulgaria, no data on the impact of growth regulators with retardant activity in spring peas are available.

The purpose of the study was to determine the effect from the application of some growth regulators with retardant activity on the morphological and productive characteristics of spring peas (*Pisum sativum* L.) grown for grain in the Stara Zagora region.

MATERIAL AND METHODS

A field experiment with spring peas variety Bogatir, was performed during the period 2007-2008, in the experimental base of the Plant Production Department at Trakia University, Stara Zagora. The experiment was realized by the block method in 4 repetitions, control plot size of 10 m2, in non-irrigated conditions, after a wheat predecessor. The soil is typically meadow-cinnamonic with medium humus content (3.42%-4.04%), normal acidity (pH in KCl-5.23-5.44), low nitrogen (31.3-38.1 mg/1000g soil) and phosphorus (3.1-4.3 mg/100 g of soil) supply and very well supplied with available potassium (42-48 mg/100 g of soil).

The effect of treatment with complex preparations was tested as followed:

Trisalvit (phenylphthalamic acid and chlorocholine chloride with retardant activity, chlorophenoxyacetic acid with auxin activity, salicylic acid and micronutrients) at doses of 300 and 400 cm^3*ha^{-1};

SM-21 (phenylphthalamic acid and chlorocholine chloride with retardant activity and trace elements) at doses of 300 and 400 cm^3*ha^{-1};

PNSA-44 (phenylphthalamic acid with retardant activity, naphthaleneacetic acid and chlorophenoxyacetic acid with auxin activity and trace elements) at doses of 200 and 300 cm^3*ha^{-1}.

The treatment with the retardant was performed at the early growth phase of pea plants (at a height of 15-20 cm) with 300 $L*ha^{-1}$ solution. Spring pea was cultivated according to the commonly adopted technology for cultivation of spring peas for this region.

During the vegetation period and the growth of pea, the main morphological characteristics and production traits were determined: height of plants at harvest, yield structure elements (number of legumes and grains from one plant, mass of the grain of a plant and 1000 grain mass) and grain yield under standard humidity (13%). The height of the stem and grain yield data were statistically processed by analysis of variance. For establishing of correlation and regression relationships software for statistical data processing StatSoft, STATISTICA for Windows (2000) was used.

RESULTS AND DISCUSSION

The success of spring pea cultivation in conditions of Central South Bulgaria low lands depends mainly on the water supply from rains during the vegetation period. The amount of rainfall in the growing season of peas in 2007 was 241.3 mm, which was by 15.6% above the average for a long period of time, but their distribution was extremely uneven (Figure 1). This year was characterized by prolonged drought in April until the last third of May as 26.6% of the growing period rainfall fell at the end of March, and 52.3% in the period 20-30 May. On the other hand in May and June during the blooming and ripening phases, the average recorded monthly air temperatures were high, by 1.6 to 2.4^{o} C above the average for the multiannual period. This led to

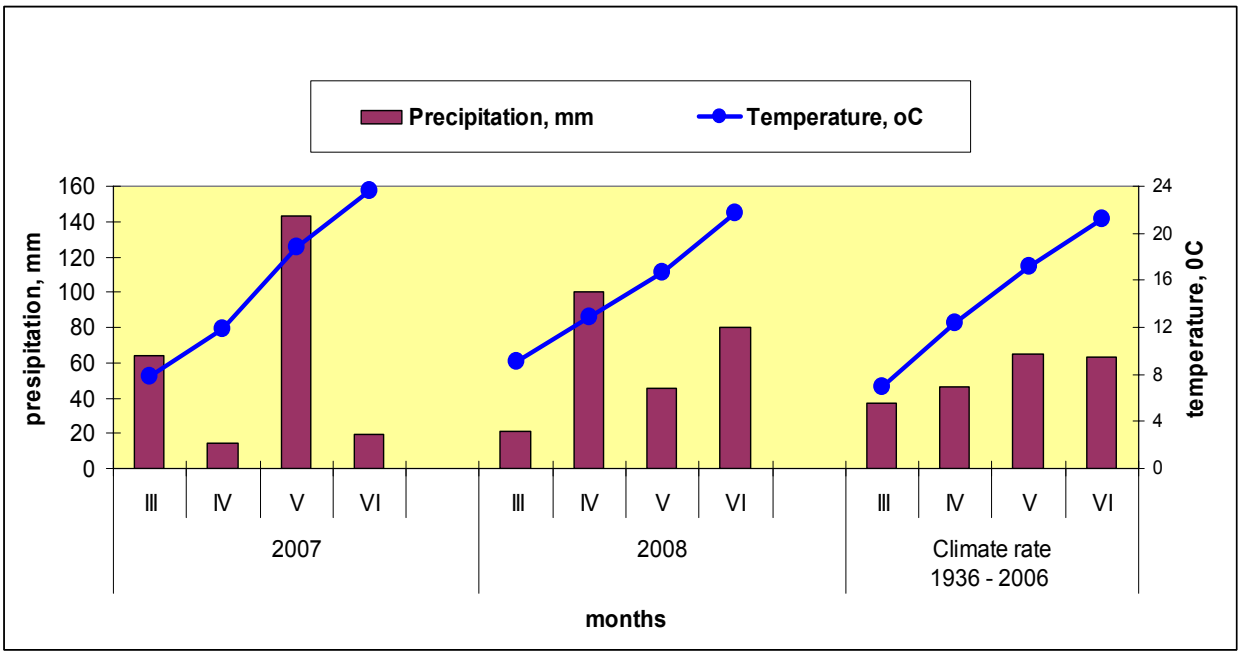

Figure 1 Monthly values of precipitation and air temperature during the growing season (March - June)
Фигура 1. Месечни стойности на валежите и температурата на въздуха през вегетационния период (март – юни)

the creation of unfavourable conditions for the development of plants and reflected negatively on their productivity.

During 2008 the conditions for growth and development of peas were more favorable. Rainfall was by 18.4% higher compared to the average for the previous 70-year period (1936 - 2006) and was distributed relatively equally - 49.1% of them fell in the first half and 50.9% in the second half of the growing season. Average monthly air temperatures in the early phases of development of the plants were above normal, but in May and June during the blooming and ripening phases were close to the average for the multiannual period.

The height of pea's stem varied significantly depending on the climate conditions during the years of investigation (Table 1). In 2007 the combination of climatic conditions during the growing season was unfavorable and led to the formation of the stalks with a very small height, 40.4 cm in average. Therefore, lying down of plants was not observed during that year. The relatively same rainfall in 2008, as well as the great precipitations in April led to the formation of plants with average stem height of 90.1 cm and in that year, lying down of plants was found out. The visual evaluation of lying down by the five degree scale (Shanin, 1977) showed 3rd degree (average rate of lying down). In plants treated with the preparation SM-21 (400 cm^3*ha^{-1}) lying down fluctuated between 3rd and 4th degree (lower extent of lying down).

Table 1 Height of plants at harvest by years and average for the period 2007 - 2008, cm
Таблица 1. Височина на растенията при прибиране по години и средно за периода 2007 - 2008 г., cm

Variants Вариант	Dose Доза cm^3*ha^{-1}	2007		2008		Average / Средно	
		cm	%	cm	%	cm	%
Control, water / Контрола, вода		43.1a	100.0	97.3a	100.0	70.2a	100.0
Trisalvit / Трисалвит	300	41.2ab	95.7	92.5 ab	95.1	66.9 ab	95.3
Trisalvit / Трисалвит	400	41.0ab	95.2	89.8bc*	92.3	65.4bc*	93.2
SM-21 / СМ-21	300	39.3bc**	91.2	88.0bc**	90.5	63.6bc**	90.7
SM-21 / СМ-21	400	37.9c***	88.0	84.5c***	86.9	61.2c***	87.2
PNSA-44 / ПНСА-44	200	40.5b*	94.0	90.8b*	93.3	65.6bc*	93.5
PNSA-44 / ПНСА-44	300	39.7bc**	92.1	88.3b**	90.8	64.0bc**	91.2
Average / Средно		40.4		90.1			
LSD,P< 0.05		2.4	5.5	6.2	6.4	4.5	5.9
LSD,P< 0.01		3.2	7.5	8.5	8.7	5.8	8.1
LSD,P< 0.001		4.4	10.2	11.5	11.9	8.0	11.0

Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants vs. control at P< 0.05; 0.01 and 0.001, respectively
*Разликите между вариантите са статистически доказани при P < 0.05 ако имат различни букви
*, **, *** - Статистическа достоверност на разликите между вариантите и контролата за P <0.05; 0.01 и 0.001

The treatment with the tested growth retardants led to reduction of the stem height. The greatest decrease was obtained after application of the preparation SM-21 (400 cm^3*ha^{-1}), where the difference vs. the control (untreated variant) - 9.0 cm (12.8%) was statistically significant ($p < 0.001$) and $P < 0.05$ vs. the Trisalvit (300 cm^3*ha^{-1}). This difference was preserved during the two years of study, regardless of the differences in the height of plants among the years. The least impact on the height of the stem was obtained after treatment with the preparation Trisalvit (300 cm^3*ha^{-1}), where the difference to the control is not statistically proven. There were no statistically significant differences among SM-21, PNSA-44 and Trisalvit (400 cm^3*ha^{-1}). For all three tested retardants, a greater effect on the height of the plants was obtained after application of the higher doses, but the difference was not statistically significant.

The yield of pea grain varied depending on the climatic conditions. The more favourable combination of climatic factors in 2008 was a prerequisite for better growth and higher yield - average 3089.6 $kg*ha^{-1}$ (Table 2). The yields in 2007 were significantly lower, when the average monthly temperatures in the period of bloom and pod forming stage of pea were unusually higher than normal and rainfall was lower than normal, especially in the blooming period.
The treatment of pea in the early growth phase with the preparation SM-21 led to reduction of the yield of grain by 2.8-3.2% (58.2-67.3 $kg*ha^{-1}$) vs controls, depending on the applied dose. For the higher retardant dose, the difference was statistically significant ($P < 0.01$) in 2008 and the average

Table 2 Yield of grain, $kg*ha^{-1}$
Таблица 2. Добив на зърно, $kg*ha^{-1}$

Variants Вариант	Dose Доза cm^3*ha^{-1}	2007 $kg*ha^{-1}$	%	2008 $kg*ha^{-1}$	%	Average / Средно $kg*ha^{-1}$	%
Control, water / Контрола, вода		1092.4a	100.0	3071.7a	100.0	2082.1a	100.0
Trisalvit / Трисалвит	300	1117.7 ac	102.3	3109.3a	101.2	2113.5ac	101.5
Trisalvit / Трисалвит	400	1087.0 a	99.5	3078.6a	100.2	2082.8 a	100.0
SM-21 / CM-21	300	1051.8b**	96.3	2996.0b*	97.5	2023.9b*	97.2
SM-21 / CM-21	400	1079.7a	98.8	2950.0b**	96.0	2014.8b**	96.8
PNSA-44 / ПНСА-44	200	1130.2c*	103.5	3182.5c**	103.6	2156.4c**	103.6
PNSA-44 / ПНСА-44	300	1159.7d***	106.2	3238.8c***	105.4	2199.3c***	105.6
Average / Средно		1102.6		3089.6		2096.1	
LSD, P < 0.05		28.2	2.6	65.5	2.1	46.8	2.4
LSD, P < 0.01		38.6	3.5	89.7	2.9	64.2	3.2
LSD, P < 0.001		52.3	4.8	122.2	4.0	87.3	4.4

Different letters indicate statistically significant differences among variants at $P < 0.05$
*, **, *** - Statistically significant differences of the variants vs control at $P< 0.05$; 0.01 and 0.001, respectively
*Разликите между вариантите са статистически доказани при $P<0.05$ ако имат различни букви
*, **, *** - Статистическа достоверност на разликите между вариантите и контролата за $P<0.05$; 0.01 и 0.001

for the period of the study. Highest yield of grain resulted from the application of the preparation PNSA-44 (300 cm^3*ha^{-1}) where the differences vs. controls were substantial ($P < 0.001$). During different years of growing, the yield of grain from this retardant exceeded by 5.4% to 6.2% control yield, and by 5.6% (117.2 $kg*ha^{-1}$) the average yield for the study period. The treatment with the preparation Trisalvit had no positive effect on pea productivity and the differences in the yield of grain were not statistically significant compared to the water control. There were no significant differences among the three retardants and between the doses for each retardant.

Tested growth regulators had a different impact on spring peas yield structure components (Table 3). Increased number of legumes and grain from the plant and higher mass of the grain were obtained by treatment with the preparation PNSA-44. For the treatment with the higher dose of this preparation (300 cm^3*ha^{-1}) the average increase was by 3.6%; 5.6% and 4.6% higher compared to the water control. The effect of PNSA- 44 at a dose of 300 cm^3*ha^{-1} for the three yield parameters was statistically significant vs. both control and to the other retardants at $P<0.05$. This explained the higher yield of grain obtained after application with Trisalvit.

The values for the number of legumes and grains of the plant and the mass of the grain of the plant after application of the preparation Trisalvit were almost equal with those in controls and not statistically significant which confirmed the lack of positive effect.

The treatment with the preparation SM-21 showed a trend towards reduction in the number of legumes, the number of grain and their mass from one plant compared to the control. Smaller numbers of grain from one plant obtained from this retardant led to a smaller mass of the grain from the plant - average 5.2 g or with by 3.7% less than controls. The difference was statistically significant to the control, PNSA–44 (the two doses) and Trisalvit - 300 cm^3*ha^{-1}.

A positive effect was observed after treatment with the preparation PNSA-44 (300 cm^3*ha^{-1}) on the 1000 grain mass of– average 211.4 g, which exceeded the control by 1.8%. The difference was statistically significant at $P<0.05$ compared to control and to other retardants. The difference among the two doses of PNSA-44 (200 and 300 cm^3*ha^{-1}) was not statistically significant. The other retardants had no significant effect on the 1000 grain mass.

The analyzed factor for establishing the influence of the three main factors (retardant, dose, year) indicated that the strongest and most statistically significant impact ($P < 0.000000$) on the height of the plants and the yield of grain was that of the conditions of the year (Table 4). The influence of the retardants on the height of plants and yield of grain was also very well exhibited ($P < 0.000009 – 0.000000$), but significantly lower. The probable reasons for this were the large variations in the meteorological conditions of the year. The interaction among retardants with the years on the yield of grain was low but statistically significant. There was no considerable interaction between retardants and applied doses between dose and year, as well as between retardants, dose and the year with respect to the height of the plants and the yield of grain.

Having in mind that productive capacity of the plants is a complex parameter depending on the effect of many factors as climate, technology,

Table 3 Structural analysis of the yield elements, mean for the period 2007 - 2008
Таблица 3. Структурен анализ на елементите на добива средно за периода 2007 -2008 г.

Variants Вариант	Dose Доза cm^3*ha^{-1}	Pods per plant / Бобове от растение		Grains per plant / Зърна от растение		Grain mass per plant / Маса на зърната от растение		1000 grain mass / Маса на 1000 зърна	
		number / брой	%	number / брой	%	G	%	G	%
Control, water / Контрола, вода		5.6ab	100.0	24.3a	100.0	5.4a	100.0	207.7a	100.0
Trisalvit / Трисалвит-300		5.6ab	100.0	24.9b*	102.3	5.5ab	100.9	208.4a	100.3
Trisalvit / Трисалвит-400		5.6ab	99.1	24.4a	100.2	5.3ac	99.1	208.4a	100.3
SM-21 / СМ-21-300		5.5a	97.3	23.9c	98.1	5.2c*	96.3	206.9a	99.6
SM-21 / СМ-21-400		5.5a	97.3	23.8c*	97.9	5.2c*	96.3	206.5a	99.4
PNSA-44 / ПНСА-44-200		5.7bc	101.8	25,1b**	103.5	5.5ab	102.8	209.1ab	100.7
PNSA-44 / ПНСА-44-300		5.8c**	103.6	25,7d***	105.6	5.7d***	104.6	211.4b*	101.8
Average / Средно		5.6		24.6		5.4		208.2	
LSD, P < 0.05		0.12		0.48		0.15		2.9	
LSD, P < 0.01		0.17		0.66		0.21		4.1	
LSD, P < 0.001		0.23		0.90		0.28		5.8	

Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants vs. control at P< 0.05; 0.01 and 0.001, respectively
*Разликите между вариантите са статистически доказани при P<0.05 ако имат различни букви
*, **, *** - Статистическа достоверност на разликите между вариантите и контролата за P<0.05; 0.01 и 0.001

morphology, it is important to establish their interaction and impact on productivity. A strong positive correlation existed between the grain yield and the height of the plants (r = 0.984, Table 5). The parameters of the height of the plants and the yield of grain in spring peas were largely dependent on the rainfall (r = 0.983 - 0.990). The effect of the rainfall on the productivity indicates a positive correlation of the grain yield with the total amount of rainfall during the growing season (March-June) and rainfall in April and June, and a negative correlation with rainfall during March and May. The amount of rainfall in April and June could be considered as critical for the development and productivity of spring pea.

Table 4 Influence of factors on the height of plants and grain yield
Таблица 4. Влияние на факторите върху височината на растенията и добива на зърно

Source of variation / Източник на вариране	Sum of squares / Сума от квадратите	Degrees of freedom / Степени на свобода	Mean squares / Средните стойности на квадрат	F	P<
Height, cm / Височина, cm					
Retardant / Ретардант	504.2	3	168.1	11.48	0.0000
Dose / Доза	31.2	1	31.2	2.13	0.1507
Year / Година	40506.6	1	40506.6	2767.23	0.0000
Retardant x Dose	12.4	3	4.1	0.28	0.8385
Retardant x Year	91.6	3	30.5	2.09	0.1145
Dose x Year	10.0	1	10.0	0.68	0.4126
Retardant x Dose x Year	3.7	3	1.2	0.08	0.9686
Error / Грешка	702.6	48	14.6		
Grain yield, $kg*ha^{-1}$ / Добив на зърно, $kg*ha^{-1}$					
Retardant / Ретардант	204026	3	68009	49.6	0.000000
Dose/ Доза	9	1	9	0.0	0.936836
Year / Година	63107930	1	63107930	46039.4	0.000000
Retardant x Dose	11468	3	3823	2.8	0.050542
Retardant x Year	50525	3	16842	12.3	0.000004
Dose x Year	549	1	549	0.4	0.529792
Retardant x Dose x Year	5636	3	1879	1.4	0.263006
Error / Грешка	65795	48	1371		

Table 5 Correlations (r) among grain yield, height of plants and precipitations
Таблица 5. Корелационни зависимости (r) между добива на зърно, височината на растенията и валежите

	Yield / Добив	Height / Височина	W_{III-VI}	W_{III}	W_{IV}	W_{V}	W_{VI}
Yield / Добив	1	0.984*	0.99*	-0.99*	0.99*	-0.99*	0.99*
Height / Височина	0.984305*	1	0.983675*	-0.98367*	0.983675*	-0.983675*	0.983675*

W_{III-VI} - total precipitation for the period March – June; W_{III} - precipitation in March; W_{IV} - precipitation in April; W_{V} - precipitation in May; W_{VI} - precipitation in June, mm
* Statistical significance at $P < 0.05$
W_{III-VI} – валежи през периода март - юни; W_{III} - валежи през март; W_{IV} - валежи през април; W_{V} - валежи през май; W_{VI} - валежи през юни, mm
*Статистическа значимост при $P < 0.05$

The good correlation obtained between the productivity and the height of the plants on one hand, and between the height of the plant, the yield of grain and rainfall on the other, allowed developing regression equations for evaluation of the parameters on the basis of climatic factors (Table 6). Yields of spring peas grain can be determined with a high accuracy depending on the rainfall during the period March-June (R^2 = 0.994) as an independent variable.

Yields of grain can be determined with a high accuracy depending on the reached final height of plants at harvest as an independent variable, but the coefficient of determination was lower (R^2 = 0.986) and the error was higher (SEE = 124.7). All regression equations had a very high degree of significance (P < 0.00001). Developed linear regression equations could be used for approximate prediction of productivity of spring peas on the basis of rainfall during the growing season.

Table 6 Regression equations for predicting the height of plants and grain yield
Таблица 6. Регресионни уравнения за предсказване на височината на растенията и добива на зърно

Equation / Уравнение	R^2	SEE	F	P<
Yield of grain, kg*ha^{-1} / Добив на зърно, kg*ha^{-1}				
Y = - 481.645+39.499 H	0.986	124.7	879.7	0.00001
Y = - 81562.1+342.6 W_{III-VI}	0.994	75.1	2449.8	0.00001
Height, cm / Височина, cm				
Y = - 2029.99+8.58 W_{III-VI}	0.987	3.06	922.9	0.00001

R^2- coefficient of determination; SEE - average error; F – ratio; P < - statistical significance; H - height of the plants, cm; W_{III-VI} - rainfall during the period March-June, mm
R^2 - коефицент на детерминация; SEE – средна грешка, F – отношение; H – височина на растенията, cm; P < - статистическа значимост; W_{III-VI} – валежи през периода март – юни, mm

CONCLUSIONS

Spring pea treatment during the early growth phase with growth retardant-type regulators resulted in reduction in the height of the stem - most pronounced (by 12.8% compared to untreated plants) after application of the preparation SM-21 (400 cm^3*ha^{-1}).

A positive effect and increased yield of grain was obtained with the preparation PNSA-44 (300 cm^3*ha^{-1}) – up to 5.6% (117.2 kg*ha^{-1}). The application of growth regulators Trisalvit and SM-21 did not affect significantly the productivity of spring peas grain.

The tested growth retardants did not result in structural abnormalities of plants. The treatment with SM-21 decreased the number and the mass of grain per plant.

A positive effect on yield structure components (number and mass of grain from one plant) and the mass of 1000 grain was established after treatment with PNSA-44 (300 cm^3*ha^{-1}), which explained the positive effect of this preparation on the pea's grain yield.

The conditions during the year had the strongest integral effect on the plant height and grain yield in comparison with retardant and doses as factors influencing pea productivity and morphology. The effect of the type of retardants was very low. The interaction among the factors was very low and had no essential effect on the height and productivity.

The productivity of spring peas was in a good positive correlation with the total amount of rainfall during the growing season and with rainfalls in April and June. This allowed the regression equations developed on the base of rains during the vegetation as an independent variable to be used for approximate assessment of spring pea productivity with a satisfactory for the practice accuracy.

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