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Buckwheat Yield Traits Response as Influenced by Row Spacing, Nitrogen, Phosphorus, and Potassium Management

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Abstract: Buckwheat is an economically important gluten free cereal, and it is a good source of protein, fiber, and energy. The field experiments with buckwheat variety "Novosadska" were set in two experimental years in Pancevo, Serbia. The aim of this study was to determine the most optimal technology for buckwheat production. The study aims were to investigate the effects of (1) row spacing: RS_1-25 cm and RS_2-50 cm; (2) nutrition variants: (N_1) 0 kg ha^{-1} NPK; (N_2) NPK 30 kg ha^{-1}; (N_3) NPK 60 kg ha^{-1}; and (N_4) NPK 90 kg ha^{-1}; (3) environment: Y_1-2018 and Y_2-2019; and their interactions on the plant height (PH), number of lateral branches (NoLB), mass of seeds per plant (MSP), number of seeds per plant (NoSP), buckwheat grain yield (GY); and (4) the correlations among these traits. All tested parameters of buckwheat significantly varied across row spacing, environment, and nutrition. The average grain yield in the row spacing, RD_1-25 cm, was significantly higher than in the wider spacing, RD_2-50 cm, and in 2018 than 2019 as well as with the nutrition NPK applied in the amount of 90 kg ha^{-1} in relation with all the other nutrition variants. All the studied agronomic traits were positively and strongly correlated with GY.

Keywords: *Fagopyrum esculentum*; nutrition; row spacing; year; productive traits; correlation

1. Introduction

Common buckwheat (*Fagopyrum esculentum* Moench; 2n = 2x = 16) is an allogamous crop, belonging to the family *Polygonaceae*, which is classified as a pseudo-cereal. It is an important crop in mountain regions. Buckwheat is characterized by a low grain yield despite an abundant of flowers formation through a long period of time [1–4]. Buckwheat grain is rich in nutrients: it contains up to 12% digestible protein, about 2% fat, 70% starch, and 0.5% sugar. Proteins are represented by glutenins and globulins. The fruits contain citric, oxalic, and malic acids, which are favorable for digestion. It also contains high levels of vitamins B1 and B2, calcium, phosphorus, and iron that are beneficial to humans. It is used as a curative herb or feed for human and animals. The overhead part of the plant in the flower is used in phytotherapy. It contains the flavone heteroside-rutin in the amount of 1.8% in the fresh leaf, about 0.7% in the flower, and very little in the stalk. The positive role of flavonoids in the treatment of capillary damage has been observed in the suppression of scurvy [2,3,5]. Chlopicka [6] has introduced rutin as the most important flavonoid in buckwheat, and it is estimated as 4–6%.

Alternative cereals, such as plain buckwheat, are of great importance for agriculture. Buckwheat is cultivated for honey because of its positive impact on the soil and for

obtaining more by-products from it. For bee grazing, it can be sown successively in five terms. Buckwheat can be used as green manure and as plants for erosion control, thus creating a source of income for farmers. It is very popular in developed countries where organic food, produced in organic production, is given great importance. Buckwheat grains are an important source of macro elements such as K, Ca, Mg, and Na as well as micro elements such as Mn, Zn, Se, and Cu [2,3,6–8], and they contain rutin, riboflavin, pyridoxine, thiamine, lysine, methionine, arginine, and threonine [9,10]. Buckwheat grain fractions showed a variation in protein content of 4.4–11.9% in flour and 19.2–31.3% in bran [11]. Buckwheat has similar protein content as cereals but significantly higher lysine content and a significantly higher biological value of protein compared to cereals. Glamočlija et al. [5] state that buckwheat belongs to so-called calliophilous plants, since it contains 40% K_2O in ash. The average protein content of buckwheat has been varied 12.0–18.9% [2,12].

Considering the fact that buckwheat has a variety of medical, industrial, and food applications, and in our country and in some other countries [13], it has not been seriously cultivated, it should be grown more extensively in multiple planting systems (summer planting) for commercial goals through seed producing. Many researchers have noticed interactions between the date and pattern of sowing with the suitable development of bushes and their role in order to sustain the soil humidity content [3,14]. Changes of plants connected with patterns of sowing with constant density can alter the conditions for light absorption concerning plant biomass. As we get closer to square and rectangular patterns, the lack of light uniformity in vegetative areas will be reduced, and by that, there may be decreased competition for absorbing the light needed for producing assimilates in leaves and stems. The grain protein content is considerably correlated with the nitrogen used from soil, and it can confirm the necessity of nitrogen fertilizer according to the plants' needs [15]. One of the most important agro-technical factors influencing the yield of grain and enabling farmers to take full advantage of the high production potential of cereals is mineral fertilization, especially nitrogen nutrition [16,17]. In intensive plant production, the level of nitrogen fertilization and the date of its application are essential for the attainment of high productivity of plants, supplying good quality yields [18]. Buckwheat's (*Fagopyrum esculentum*) response to nitrogen depends on the primary nitrogen content of the soil, climatic conditions, and nitrogen additives as well as its addition time [3,19]. The buckwheat variety "Novosadska" is one of the most represented varieties in Serbia. Knowledge of the biological properties of the plant itself and its requirements according to environmental conditions form the basis of the cultivation technology. The important agro-technical measures in buckwheat production are nutrition and row spacing [4,19]. Optimizing harvestable buckwheat grain yield requires matching the buckwheat genotype with optimal agro-technical practices [2,20]. A crop will express its full potential only when it is backed up by good agronomic practices. Optimum row spacing and plant density provide conditions for proper light interception throughout the crop growth period. Plant density has important effects on the vegetative and reproductive development of buckwheat [10]. Buckwheat yield is low if the density of plants is low [1,19,20]. All these factors influence the crop growth, seed yield, and quality parameters. Nutrients are important and crucial elements, which are required for the plant for its growth and development. The translocation of photosynthates from the source through the plant is very important for the development of those parts of the plant that are important for the economy.

Row spacing, sowing date, and nitrogen greatly influence the amount of fat, starch, protein content, and seed yield. There was an evident influence of row spacing and N nutrition increase on the protein content [5,15].

The aim of this research was to determine the most optimal technology for buckwheat production, including quantities of nutrition and the method of row spacing (in narrow or wide rows), to produce the highest buckwheat yields. Wide and narrow row spacing are recognized as good management practices in crop production. Optimizing nutrition and row spacing in order to maximize profitability is of great importance in the future buckwheat production in Pannonian environments.

2. Materials and Methods

In order to investigate the influence of the rows spacing and NPK nutrition on the morphological and productive traits of buckwheat, experiments were conducted during 2018 and 2019 in Pancevo, 44°52'14" N 20°38'25" E, 77 m.s.l., Serbia, on brown soil. The subject of the study was the variety Novosadska, which was selected at the Institute of Field and Vegetable Crops, Novi Sad. The size of the basic plot was 6 m^2 for sowing in 25 cm and 50 cm. The experiment was laid out in a split plot design with three replications having two row spacings (RS$_1$-25 cm and RS$_2$-50 cm) as the main plots and four nutrient levels (N$_1$-0 NPK kg ha^{-1}, N$_2$-30 NPK kg ha^{-1}, N$_3$-60 NPK kg ha^{-1}, and N$_4$-90 NPK kg ha^{-1}) as sub plots. A standard agro-technical measures was applied.

The sowing of buckwheat should be done at a 25 cm and 50 cm row spacing, with the consumption of about 60 and 40 kg of seeds/ha [21]. The crop was watered three times with 30 L of water in April, May, and June. The crop preceding buckwheat in both years was winter wheat. The basic tillage was done in the autumn, and secondary tillage was done just before the sowing. Manual sowing was done in mid-April, when the planned nutrients were introduced; 4 rows of 3 m length, in each variant, were sown. Other crop management practices were carried out in accordance with local agronomic practices. Crop was harvested at the stage of technological maturity. Other agro-technical measures were carried out in accordance with local agronomic practices. Crop was harvested at the stage of technological maturity. From all nutrition variants and row spacing, 10 plants were taken from two middle rows for laboratory analyses of morphological and fertility traits. For the morphological traits, the plant height and the number of lateral branches per plant were studied; then, for the fertility traits, the number of seeds per plant and seed mass per plant were analyzed as well as yield as a productivity indicator. Grains from single plots were cleaned, dried, and the weight was recorded. Grain yield was measured in each experimental plot separately and adjusted to 13% of moisture, and the yield per hectare was recalculated.

2.1. Soil Conditions

Plant yield strongly depends on the soil conditions in which the root system develops. The quality of soil conditions is defined by the favorable water–air regime, mechanical composition, and supply of soil nutrients [22–31]. The soil in the experimental plot had, at depths of 0–30 cm and 30–60 cm, a low alkaline and neutral reaction (pH in H$_2$O = 7.01 and 6.50). There was carbonate (7.20% and 6.61%) well provided with humus (3.69% and 3.40%), phosphorus (26.30 and 20.11 mg/100 g soil) and potassium (28.90 and 23.70 mg/100 g soil); see Table 1.

Table 1. Chemical composition of the brown earth type of soil in Pancevo, Serbia.

Parameter	pH		Humus	CaCO$_3$	P$_2$O$_5$	K$_2$O
Depth (cm)	H$_2$O	KCl	(%)	(%)	mg/100 g Soil	
1–30	7.01	6.77	3.69	7.20	26.30	28.90
30–60	6.50	6.10	3.40	6.61	20.11	23.70

2.2. Meteorological Data

Meteorological data regarding temperature and precipitation are very variable. Climate change significantly affects crop production [2,32]. During the survey, meteorological indicators were monitored and analyzed: temperatures, amounts, and the schedule of precipitation during the buckwheat vegetation period (Figure 1a,b). Data on monthly precipitation and air temperatures for 2018 and 2019 were taken from the Hydro-meteorological Institute of the Republic of Serbia for Pancevo (Figure 2a,b). The total precipitation in the surveyed years was slightly lower than in the multi-year period (by 18.6 mm and 5 mm), but the order of precipitation was different. The highest precipitation in 2018 and 2019 was recorded in July (90 mm and 93 mm), which is 36 mm and 38.1 mm higher than the

average, while in April, May, and August, there was less precipitation than the average. The average daily temperatures in the years studied were slightly higher compared to the multi-year period (by 0.3 °C and 0.1 °C). The highest temperatures in 2018 and 2019 were recorded in August (23.9 °C and 24.7 °C), which is 0.4 °C and 1.2 °C higher than the multi-annual average, while in April, June, and July, the temperatures were less than the perennial average, as shown in Figure 1a.
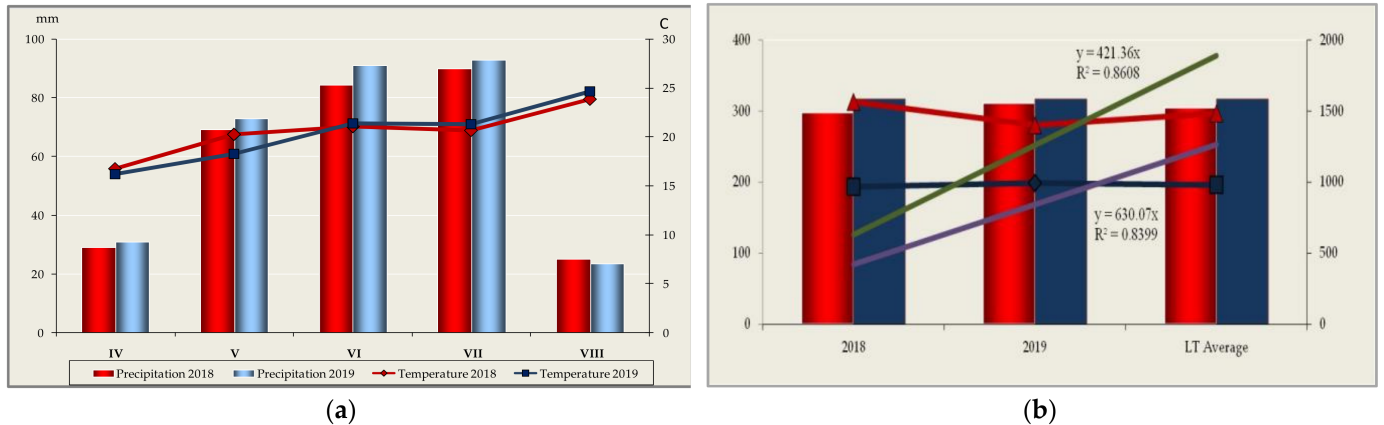

Figure 1. Temperature (°C) and precipitation (mm) in Pancevo, 2018–2019, Serbia (**a**); Average grain yield in buckwheat in tested years across the world and in Serbia (**b**).
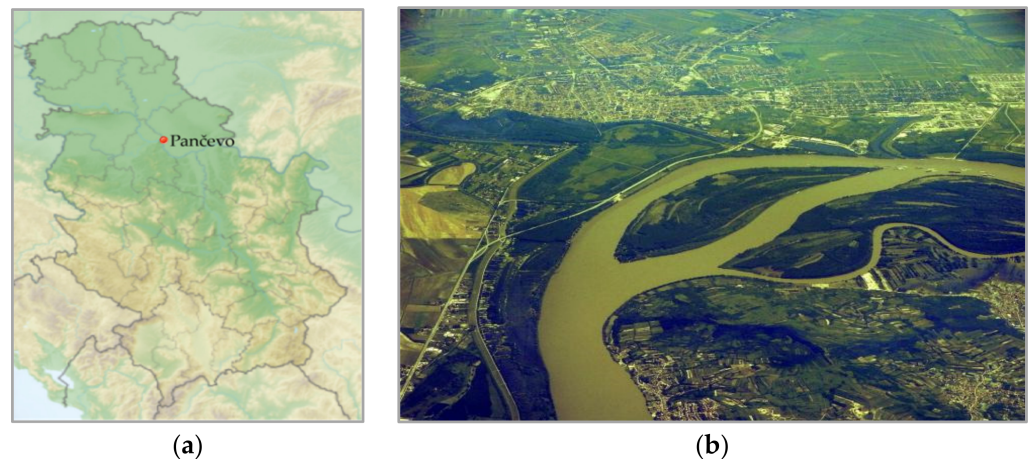
Figure 2. Locality Pancevo on the map of Serbia (**a**); Municipality of Pancevo, in the South Banat district, Serbia (**b**).

A more favorable buckwheat production year was 2018 compared to 2019. In 2018, the total precipitation (298 mm) decreased by 13.6 mm and the average temperatures increased by 0.2 °C, but the precipitation schedule and temperature were much more favorable compared to 2019. In May, there was 2.9 mm less precipitation and temperatures were higher by 2 °C, which led to better initial growth and gave a nice set of plants that overshadowed the weeds with their growth habit.

In August, there were more favorable conditions in 2018; there was 1.8 mm more precipitation, but temperatures were lower by 1.2 °C (23.9 °C) compared to 2019 (24.7 °C), which provided uniform maturing and greater yields.

2.3. Statistical Analysis

The experimental data obtained were analyzed using descriptive and analytical statistics using the statistical package STATISTICA 12 for Windows. Significance testing of differ-

ences between the calculated mean values of the examined factors (years, nutrition variant, and row sowing method) was performed using a three-factor model of variance analysis:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{il} + (\beta\gamma)_{jl} + \varepsilon_{ijlk}, \ i = 1, 2; \ j = 1, 2; \ l = 1, 2, 3, 4; \ k = 3 \quad (1)$$

All significance ratings were based on the F-test and LSD test for significance levels of 0.05% and 0.01%. The relative dependence was determined by the method of correlation analysis (Pearson's correlation coefficients), and the obtained coefficients were tested by *t*-test for significance levels of 0.05% and 0.01%.

3. Results

The world's current average buckwheat production, in the tested period, was 3,439,088 t. The average area under buckwheat crop in the world in the tested period was 3,499,290 ha and the average buckwheat yield in the world was 981 kg ha^{-1}, according to the FAO [33]; see Figure 1b. Buckwheat is an alternative crop in the Republic of Serbia. Areas under buckwheat are small, around 150 ha. Nevertheless, buckwheat cultivation is profitable considering its low input requirements.

3.1. Grain Yield of Buckwheat in Serbia

The results of 2-year studies of the influence of agro-meteorological conditions on buckwheat grain yield showed that they significantly influence the success in the production of this alternative grain. Average grain yields in Serbia, in the tested year, varied from 1.0 to 1.6 t ha^{-1} (Table 2, Figure 3a,b).

Table 2. Effect of row spacing (cm), year, and nutrition variant (kg ha^{-1}) on grain yield (kg ha^{-1}).

Parameter/Grain Yield, kg ha^{-1}	2018	2019	Average
RS—Row Spacing, cm	Average Value $\pm$ Stand. Dev.		
25	1846.50 $\pm$ 371.26	1670.83 $\pm$ 358.92	1758.66 $\pm$ 368.22
50	1284.50 $\pm$ 322.35	1134.00 $\pm$ 222.35	1209.25 $\pm$ 281.47
Total	1565.50 $\pm$ 444.50	1402.42 $\pm$ 400.55	1483.96 $\pm$ 426.84
NPK levels, RS$_1$			
0	1354.66 $\pm$ 40.46	1280.00 $\pm$ 40.00	1317.33 $\pm$ 54.47
30	1780.66 $\pm$ 135.68	1386.66 $\pm$ 23.09	1583.66 $\pm$ 232.69
60	1976.00 $\pm$ 108.68	1943.33 $\pm$ 28.87	1959.66 $\pm$ 73.34
90	2274.66 $\pm$ 238.17	2073.33 $\pm$ 30.55	2174.00 $\pm$187.68
Average	1846.50 $\pm$ 371.26	1670.83 $\pm$ 358.92	1758.67 $\pm$ 368.21
NPK levels, RS$_2$			
0	958.00 $\pm$ 96.89	1073.33 $\pm$ 291.43	1015.66 $\pm$ 204.25
30	1148.00 $\pm$ 113.33	989.33 $\pm$ 16.17	1068.66 $\pm$ 113.15
60	1265.33 $\pm$ 73.38	1040.00 $\pm$ 20.00	1152.66 $\pm$ 132.46
90	1766.66 $\pm$ 80.82	1433.33 $\pm$ 41.63	1600.00 $\pm$ 191.42
Average	1284.25 $\pm$ 322.29	1134.00 $\pm$ 222.35	1209.25 $\pm$ 281.48
Average NPK levels			
0	1156.33 $\pm$ 227.17	1176.66 $\pm$ 217.77	1166.50 $\pm$ 212.44
30	1464.33 $\pm$ 364.12	1188.00 $\pm$ 218.37	1326.16 $\pm$ 320.57
60	1620.66 $\pm$ 397.98	1491.66 $\pm$ 495.27	1556.16 $\pm$ 433.63
90	2020.66 $\pm$ 320.50	1753.33 $\pm$ 352.06	1887.00 $\pm$ 350.03
Average	1565.50 $\pm$ 444.96	1402.41 $\pm$ 400.55	1483.95 $\pm$ 426.83

P	LSD	Y	RS	V	RS $\times$ Y	RS $\times$ V	V $\times$ Y	RS $\times$ Y $\times$ V
GY	0.5	68.022	68.022	96.209	96.209	136.061	136.061	192.418
	0.1	91.488	91.488	129.398	129.398	182.998	129.998	258.798

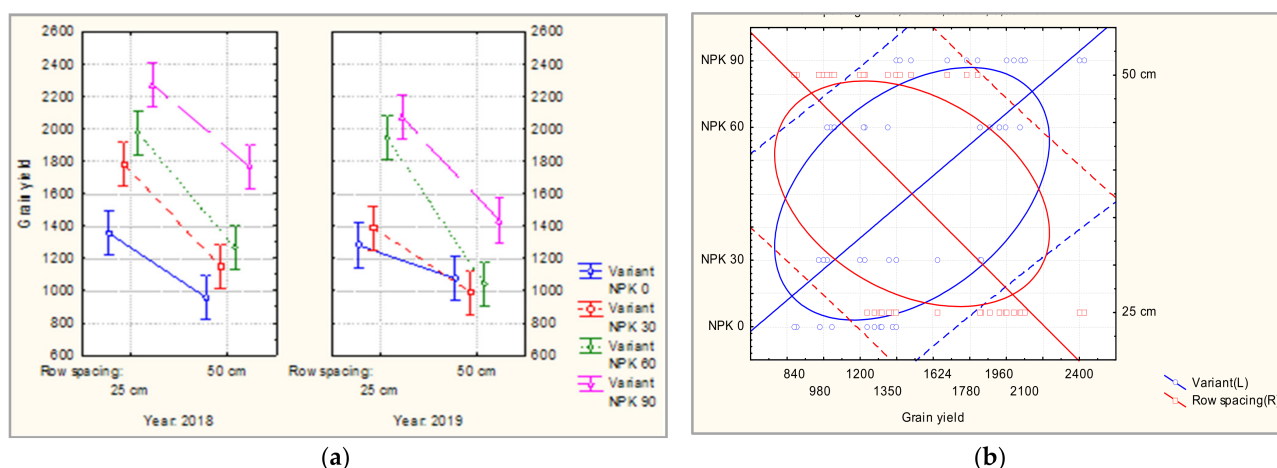P—Parameter; GY—Grain yield; Y—Year; RS—Row spacing; V—Variant.

Figure 3. Effect of row spacing and NPK nutrition on GY (**a**), and interaction of year, row spacing, and NPK on yield (**b**).

The grain yield of buckwheat is influenced by year, row spacing, and variant nutrition (Table 2, Figure 3a,b). The seed yield was significantly influenced by all factors examined: row spacing, test year, and nutrition ($p < 0.05$ and $p < 0.01$).

The interaction of the investigated factors, V × Y, Y × SD, and SD × V had a significant effect on the investigated parameters ($p < 0.05$, Figure 3a). In 2018, a significantly higher seed yield was achieved ($Y_1 = 1565.5$ kg ha^{-1}) compared to 2019 ($Y_2 = 1402.4$ kg ha^{-1}) ($p < 0.05$, Table 2).

At narrower row spacing, significantly higher seed yield was achieved ($RS_1 = 1758.7$ kg ha^{-1}) relative to the wider spacing ($RD_2 = 1209.3$ kg ha^{-1}) (Table 2, Figure 3a,b).

The highest grain yield (2020.66 kg ha^{-1}) was achieved in 2018 in nutrition variant with an application of 90 kg NPK; see Table 2.

A significantly lower average seed yield for the studied period was achieved in the control variant ($N_1 = 1166.5$ kg ha^{-1}) compared to the nutrition variants. The average seed yield increased with nutrient growth ($N_2 = 1326.2$ kg ha^{-1}, $N_3 = 1556.2$ kg ha^{-1}, and $N_4 = 1887.0$ kg ha^{-1}). A significantly higher seed yield was obtained in nutrition variant N_4 compared to variants N_1 and N_2 ($p < 0.01$, Tables 2 and 3).

Table 3. ANOVA for the grain yield.

Parameter	Grain Yield				
Effect	SS	Deg. of Freed.	MS	*F*-Value	*p*-Value
Intercept	105,702,352	1	105,702,352	7903.620 **	0.000000
Row spacing—RS	3,622,304	1	3,622,304	270.848 **	0.000000
Year—Y	319,154	1	319,154	23.864 **	0.000028
Nutrition variant—V	3,520,016	3	1,173,339	87.733 **	0.000000
RS × Y	1900	1	1900	0.142 ns	0.708716
RS × V	388,554	3	129,518	9.684 **	0.000107
Y × V	175,491	3	58,497	4.374 *	0.010887
RS × Y × V	107,620	3	35,873	2.682 ns	0.063298
Error	427,965	32	13,374		

SS—Sum of Squares; MS—Mean of Squares; ns—Nonsignificant; *—Significant at the 0.05 probability level; **—Significant at the 0.01 probability level.

Based on the analysis of variance, it can be concluded that there are highly significant differences in the grain yield between the tested years ($F_{exp} = 23.864$ **), row spacing ($F_{exp} = 270.848$ **), and nutrition ($F_{exp} = 87.733$ **); see Table 3. The interaction of RS × V had a highly significant effect on grain yield ($F_{exp} = 9.684$ **), while the Y × V interaction had a significant effect on grain yield ($F_{exp} = 4.374$ *); see Table 3.

3.1.1. Buckwheat Plant Height

The plant height of buckwheat was affected by RS and V levels, as shown in Table 4. Plant height was significantly influenced by all factors examined and their interaction ($p < 0.05$ and $p < 0.01$; Table 4, Figure 4a,b).

Table 4. Effect of row spacing (cm), year, and nutrition variant (kg ha^{-1}) on plant height.

Parameter/Plant Height, cm			2018	2019		Average
Row Spacing, cm			**Average Value $\pm$ Stand. Dev.**			
25			118.20 ± 11.25	118.80 ± 5.94		118.50 ± 8.82
50			108.43 ± 5.94	119.94 ± 17.64		114.19 ± 15.98
Total			113.31 ± 12.56	119.37 ± 12.88		116.34 ± 12.95
NPK levels, RS$_1$						
0			106.90 ± 0.26	93.33 ± 2.12		100.12 ± 7.55
30			117.03 ± 0.38	104.16 ± 7.22		110.60 ± 8.41
60			113.10 ± 0.61	115.87 ± 4.67		114.48 ± 3.34
90			135.77 ± 1.07	120.33 ± 9.28		128.05 ± 10.31
Average			118.20 ± 11.26	108.43 ± 12.28		113.31 ± 12.55
NPK levels, RS$_2$						
0			109.50 ± 0.26	92.20 ± 4.65		100.85 ± 9.23
30			123.40 ± 0.36	124.73 ± 3.20		124.07 ± 2.17
60			118.87 ± 0.51	126.47 ± 3.29		122.67 ± 4.66
90			123.43 ± 0.45	136.37 ± 3.51		129.90 ± 7.43
Average			118.80 ± 5.94	119.94 ± 17.64		116.34 ± 12.95
Average NPK levels						
0			100.11 ± 7.55	92.77 ± 3.29		100.48 ± 8.41
30			120.22 ± 3.50	114.45 ± 12.32		117.33 ± 9.14
60			115.98 ± 3.19	124.07 ± 2.16		118.57 ± 5.76
90			129.60 ± 6.79	122.66 ± 4.66		128.98 ± 8.62
Average			116.48 ± 12.94	113.49 ± 12.24		114.98 ± 15.64
Average 2018–2019			118.50 ± 8.81	114.18 ± 15.98		116.34 ± 12.95
P	**LSD**	**Y**	**RS**	**V**	**RS $\times$ Y**	**RS $\times$ V**	**V $\times$ Y**	**RS $\times$ Y $\times$ V**

P	LSD	Y	RS	V	RS $\times$ Y	RS $\times$ V	V $\times$ Y	RS $\times$ Y $\times$ V
PH	0.5	2.191	2.191	3.098	3.098	4.382	4.382	6.197
	0.1	2.937	2.937	4.153	4.153	5.874	5.874	8.306

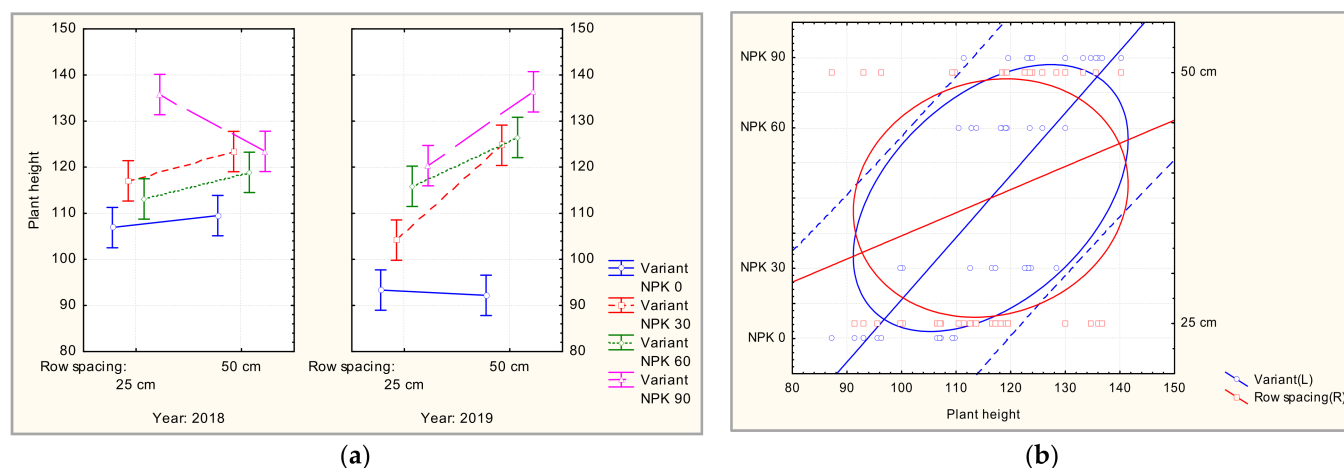P—Parameter; PH—Plant height; Y—Year; RS—Row spacing; V—Variant.

Figure 4. Effect of row spacing and NPK nutrition on PH (**a**), and interaction of year, row spacing, and NPK on plant height (**b**).

Based on the analysis of variance, it can be concluded that there are highly significant differences in the plant height between tested years (F_{exp} = 16.12 **), row spacing (F_{exp} = 31.75 **), and nutrition (F_{exp} = 120.27 **); see Table 5.

Table 5. ANOVA for the plant height.

Parameter	Plant Height				
Effect	SS	Deg. of Freed.	MS	*F*-Value	*p*-Value
Intercept	649,698.40	1	649,698.58	46,840.58 **	0.00000
Row spacing—RS	440.40	1	440.45	31.75 **	0.00000
Year—Y	223.60	1	223.60	16.12 **	0.00033
Nutrition variant—V	5004.71	3	1668.20	120.27 **	0.00000
RS × Y	357.51	1	357.50	25.78 **	0.00001
RS × V	316.40	3	105.50	7.60 *	0.00056
Y × V	676.01	3	225.30	16.25 **	0.00000
RS × Y × V	425.20	3	141.70	10.22 **	0.00007
Error	443.91	32	13.90		

SS—Sum of Squares; MS—Mean of Squares; * and **—Significant at the 0.05 and 0.01 probability level.

The interaction of RS × Y, Y × V, and RS × Y × V had a highly significant effect on plant height (F_{exp} = 25.78 **; F_{exp} = 16.25 **; F_{exp} = 10.22 **), while the RS × V interaction had a significant effect on plant height (F_{exp} = 7.60 *); see Table 5.

Significantly lower average values for plant height, for the studied period, were achieved in the control variant (N_1 = 100.48 cm) compared to the variants with nutrition.

Average values for the height of buckwheat plants increased with the growth of nutrients (117.33, 118.58, and 128.97 cm for N_2, N_3, and N_4, respectively). Significantly higher values for plant height were obtained in variant N_4 compared to variants N_1, N_2, and N_3 ($p < 0.01$, Table 4).

According to Lalevic et al. [17], the conditions of the external environment, as well as the certain nutritional elements, significantly influenced the plant height and thousand grain weight.

3.1.2. Number of Lateral Branches per Plant

The effects of year, row spacing, and nutrition variant on the number of lateral branches per plant (NoLB) of buckwheat are shown in Tables 6 and 7 and Figure 5a.

The number of lateral branches per plant was significantly influenced by year, nutrition, and the interaction of RS × V, Y × V, and the interaction of RS × Y × V ($p < 0.05$ and $p < 0.01$).

In 2018, significantly smaller NoLB values were achieved compared to 2019 ($p < 0.05$). Row spacing had a nonsignificant effect on NoLB. There were more lateral branches in the wider row spacing (Table 6, Figure 5b).

A significantly smaller average NoLB during the study period was achieved in the control variant (N_1 = 1.94) compared to other variants of nutrition. The average value of the NoLB increased with the increase in nutrients. A significantly higher value of NoLB was achieved in variant N_4 compared to variant N_1 ($p < 0.01$, Table 6, Figure 5a,b).

On the basis of the ANOVA, the years, nutrition, interaction of RS × V, Y × V, and interaction of RS × Y × V had a significant influence on the NoLB ($p < 0.05$ and $p < 0.01$; F_{exp} = 10.010 **; F_{exp} = 33.420 **; F_{exp} = 31.080 **, respectively). The row spacing had a nonsignificant effect on the number of lateral branches, F_{exp} = 0.050 * and RS × V interaction, F_{exp} = 0.851; see Table 7. In 2018, there were significantly fewer lateral branches per plant compared to 2019 ($p < 0.05$).

Table 6. Effect of row spacing (cm) and nutrition (kg ha^{-1}) of number of lateral branches per plant.

Parameter/NoLB, nr Plant^{-1}	2018	2019	Average
Row Spacing, cm	**Average Value $\pm$ Stand. Dev.**		
25	2.44 $\pm$ 0.57	2.42 $\pm$ 0.56	2.43 $\pm$ 0.55
50	2.89 $\pm$ 0.56	2.93 $\pm$ 0.61	2.91 $\pm$ 0.55
Total	2.42 $\pm$ 0.56	2.91 $\pm$ 0.55	2.67 $\pm$ 0.60
NPK levels, RS$_1$			
0	1.56 $\pm$ 0.15	2.10 $\pm$ 0.17	1.94 $\pm$ 0.46
30	2.46 $\pm$ 0.06	2.87 $\pm$ 0.06	2.71 $\pm$ 0.24
60	2.73 $\pm$ 0.15	3.20 $\pm$ 0.10	2.81$\pm$ 0.27
90	3.00 $\pm$ 0.10	3.40 $\pm$ 0.10	2.23 $\pm$ 0.53
Average	2.44 $\pm$ 0.57	2.89 $\pm$ 0.53	2.67 $\pm$ 0.58
NPK levels, RS$_2$			
0	2.10 $\pm$ 0.17	2.56 $\pm$ 0.06	2.05 $\pm$ 0.57
30	2.86 $\pm$ 0.06	2.57 $\pm$ 0.15	2.75 $\pm$ 0.26
60	3.20 $\pm$ 0.10	2.67 $\pm$ 0.06	2.65 $\pm$ 0.14
90	3.40 $\pm$ 0.10	3.93 $\pm$ 0.06	3.25 $\pm$ 0.75
Average	2.89 $\pm$ 0.52	2.93 $\pm$ 0.61	2.68 $\pm$ 0.63
Average NPK levels			
0	1.55 $\pm$ 0.12	2.33 $\pm$ 0.28	1.94 $\pm$ 0.46
30	2.70 $\pm$ 0.28	2.71 $\pm$ 0.19	2.70 $\pm$ 0.24
60	2.68 $\pm$ 0.17	2.93 $\pm$ 0.30	2.80 $\pm$ 0.26
90	2.78 $\pm$ 0.24	3.67 $\pm$ 0.30	3.23 $\pm$ 0.61
Average	2.42 $\pm$ 0.24	2.91 $\pm$ 0.55	2.66 $\pm$ 0.61
Average 2018–2019	2.67 $\pm$ 0.58	2.68 $\pm$ 0.63	2.67 $\pm$ 0.60

P	LSD	Y	RS	V	RS $\times$ Y	RS $\times$ V	V $\times$ Y	RS $\times$ Y $\times$ V
NLB	0.5	0.074	0.074	0.104	0.104	0.147	0.147	0.208
	0.1	0.099	0.099	0.139	0.139	0.197	0.197	0.278

P—Parameter; NoLB—Number of lateral branches; Y—Year; RS—Row spacing; V—Variant.

Table 7. ANOVA for the number of lateral branches per plant.

Parameter	Number of Lateral Branches				
Effect	**SS**	**Deg. of Freed.**	**MS**	**F**	**p**
Intercept	342.4008	1	342.4008	21,913.650 **	0.000000
Row spacing—RS	0.0008	1	0.0008	0.050 [ns]	0.818830
Year—Y	2.8033	1	2.8033	179.410 **	0.000000
Nutrition variant—V	10.3092	3	3.4364	219.930 **	0.000000
RS $\times$ Y	0.0133	1	0.0133	0.851 [ns]	0.362525
RS $\times$ V	0.4692	3	0.1564	10.010 **	0.000083
Y $\times$ V	1.5667	3	0.5222	33.420 **	0.000000
RS $\times$ Y $\times$ V	1.4567	3	0.4856	31.080 **	0.000000
Error	0.5000	32	0.0156		

SS—Sum of Squares; MS—Mean of Squares; [ns]—Nonsignificant; **—Significant at the 0.01 probability level.
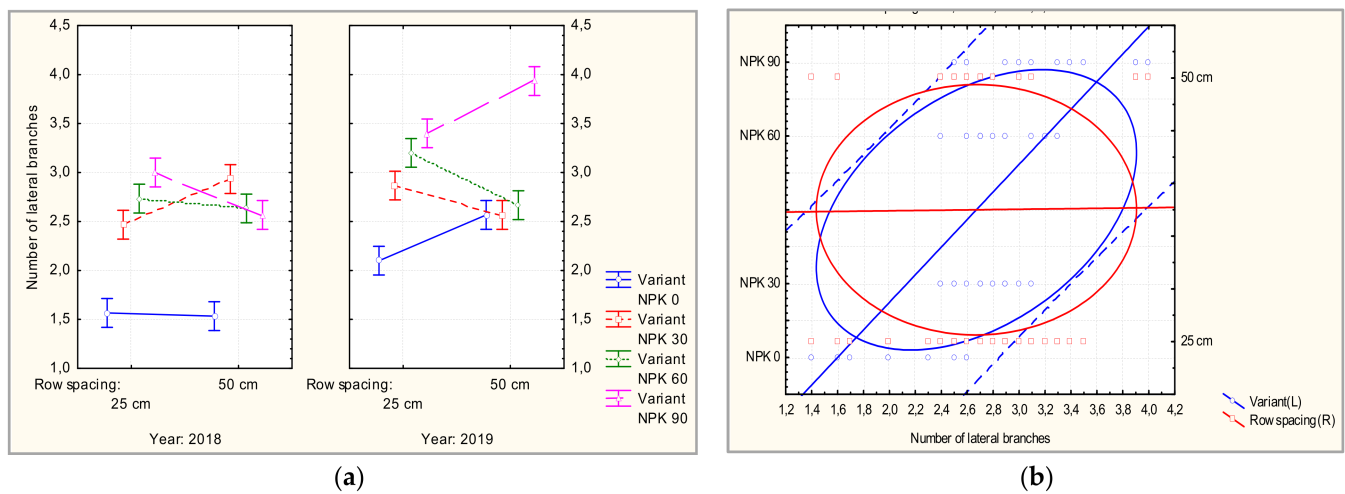
Figure 5. Effect of row spacing and NPK nutrition on NLB (**a**) and interaction of year, row spacing, and NPK on NLB (**b**).

3.1.3. Mass of Seed per Plant

In 2018, a significantly higher MSP (Y_1 = 0.94 g) was achieved compared to 2019 (Y_2 = 0.77 g) ($p < 0.05$; Table 8). At narrow row spacing, a significantly higher MSP (RS_1 = 0.94 g) was achieved compared to wider row spacing (RS_2 = 0.76 g) (Table 8, Figure 6a,b).

Table 8. Effect of row spacing (cm) and nutrition variant (kg ha^{-1}) of mass of seed per plant (MSP).

Parameter/Mass of Seed, g Plant^{-1}			2018	2019	Average
Row Spacing, cm			**Average Value ± Stand. Dev.**		
25			1.00 ± 0.37	0.87 ± 0.23	0.93 ± 0.31
50			0.87 ± 0.41	0.66 ± 0.18	0.77 ± 0.33
Total			0.94 ± 0.30	0.77 ± 0.32	0.85 ± 0.33
NPK levels, RS_1					
0			0.60 ± 0.10	0.57 ± 0.06	0.58 ± 0.14
30			0.80 ± 0.10	0.78 ± 0.08	0.79 ± 0.13
60			1.20 ± 0.10	1.03 ± 0.08	1.12 ± 0.16
90			1.40 ± 0.11	1.11 ± 0.11	1.26 ± 0.21
Average			1.00 ± 0.37	0.87 ± 0.42	0.94 ± 0.39
NPK levels, RS_2					
0			0.60 ± 0.20	0.48 ± 0.07	0.54 ± 0.15
30			0.64 ± 0.32	0.64 ± 0.15	0.64 ± 0.22
60			1.00 ± 0.40	0.67 ± 0.14	0.84 ± 0.32
90			1.27 ± 0.42	0.85 ± 0.12	1.06 ± 0.36
Average			0.88 ± 0.41	0.66 ± 0.18	0.77 ± 0.33
Average NPK levels					
0			0.60 ± 0.17	0.52 ± 0.08	0.56 ± 0.13
30			0.72 ± 0.26	0.71 ± 0.13	0.71 ± 0.19
60			1.10 ± 0.31	0.85 ± 0.22	0.97 ± 0.28
90			1.33 ± 0.30	0.98 ± 0.18	1.16 ± 0.29
Average			0.93 ± 0.30	0.76 ± 0.32	0.85 ± 0.32

P	**LSD**	**Y**	**RS**	**RS × Y**	**RS × V**	**V × Y**	**RS × Y × V**
MSP	0.5	0.126	0.125	0.177	0.251	0.252	0.355
	0.1	0.169	0.169	0.239	0.338	0.337	0.478

P—Parameter; MSP—Mass of seed per plant; Y—Year; RS—Row spacing; V—Variant.
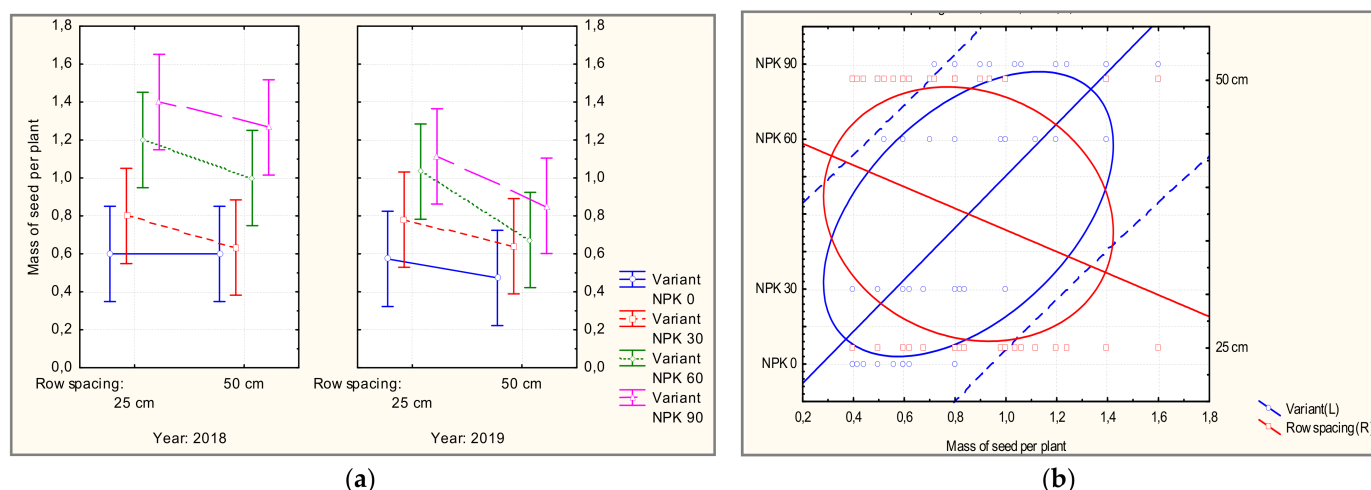
(**a**)   (**b**)

Figure 6. Effect of row spacing and NPK nutrition on MSP (**a**), and interaction of year, row spacing, and NPK on MSP (**b**).

A significantly lower average mass of seed per plant, in the study period, was achieved in the control variant ($N_1 = 0.56$ g) compared to other nutrition treatments. The average seed mass grew with the increase in variants. Significantly higher MSP was in variant N_4 compared to variants N_1 and N_2 ($p < 0.01$; Table 8).

The mass of seed per plant (MSP) was significantly influenced by all factors examined ($p < 0.01$; Table 9, Figure 6a,b). On the basis of the ANOVA, the row spacing, years, and nutrition had a highly significant influence on the MSP ($p < 0.01$; $F_{exp} = 7.6150$ **; $F_{exp} = 7.6151$ **; $F_{exp} = 18.6996$ **, respectively). They had a nonsignificant effect on the interaction of the tested factor; see Table 9.

Table 9. ANOVA table for the mass of seed per plant.

Parameter	Mass of Seed per Plant				
Effect	SS	Deg. of Freed.	MS	*F*-Value	*p*-Value
Intercept	34.88430	1	34.88430	765.9865 **	0.00000
Row spacing—RS	0.34680	1	0.34680	7.6150 **	0.00949
Year—Y	0.34680	1	0.34680	7.6150 **	0.00949
Nutrition variant—V	2.55483	3	0.85160	18.6996 **	0.00000
RS × Y	0.02430	1	0.02430	0.5336 ns	0.47042
RS × V	0.08247	3	0.02749	0.6036 ns	0.61745
Y × V	0.22100	3	0.07367	1.6176 ns	0.20465
RS × Y × V	0.01497	3	0.00499	0.1096 ns	0.95390
Error	1.45733	32	0.04554		

SS—Sum of Squares; MS—Mean of Squares; ns—Nonsignificant; **—Significant at the 0.01 probability level.

In addition, our research findings align with those of Popovic et al. [19]; they state that the inter-row spacing and nutrition had significant effects on MSP. Significantly lower MSP and seed yield were achieved at a 50 cm row spacing and in the control variant compared to the variants where nutrition was added. Depending on the row spacing, MSP varied from 0.45 g (50 cm) to 0.50 g (25 cm), while seed yield varied from 700 kg ha^{-1} (50 cm) to 980 kg ha^{-1} (25 cm). Significantly lower yields were achieved in the control variant compared to the variant with added nutrition.

3.1.4. Number of Seeds per Plant

The number of seeds per plant (NoSP) was significantly affected by all factors examined ($p < 0.01$; Figure 7a,b). In 2018, a significantly higher NoSP was achieved compared

to 2019 (Table 10). In narrower row spacing, a significantly higher NoSP was achieved compared to wider spacing (Tables 10 and 11).
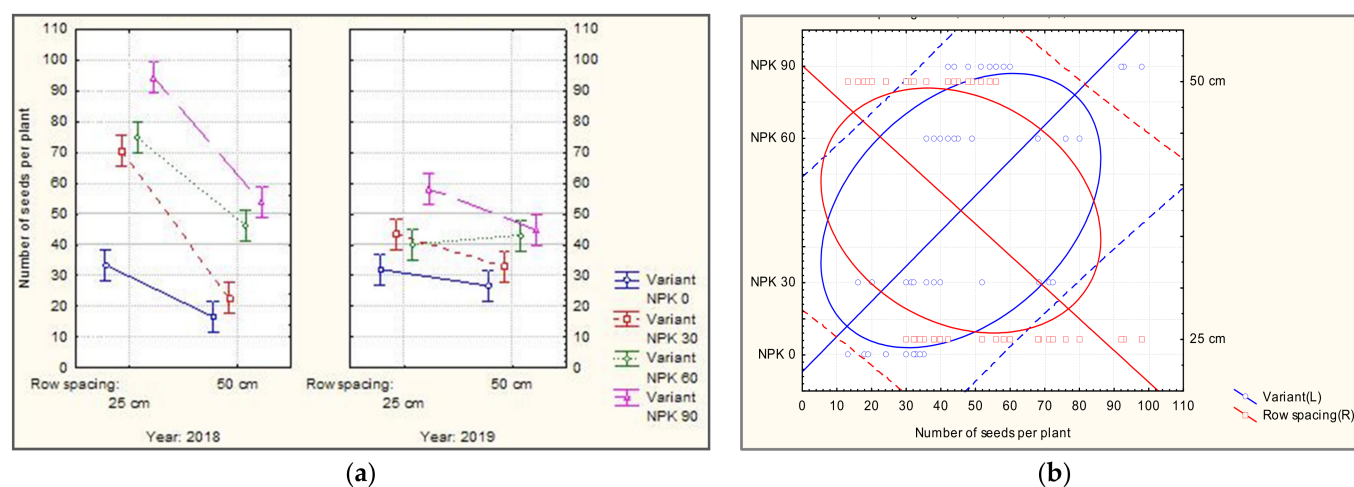

Figure 7. Effect of row spacing and NPK nutrition on NoSP (**a**), and interaction of year, row spacing, and NPK on NoSP (**b**).

Table 10. Effect of row spacing (cm) and nutrition variant (kg ha^{-1}) on the number of seeds per plant.

Parameter/Number of Seed, nr Plant^{-1}		2018		2019			Average
Row Spacing, cm				Average Value $\pm$ Stand. Dev.			
25		68.27 $\pm$ 23.18		43.33 $\pm$ 10.33			55.80 $\pm$ 21.72
50		34.77 $\pm$ 16.72		36.75 $\pm$ 8.66			35.76 $\pm$ 13.06
Total		51.52 $\pm$ 26.14		40.04 $\pm$ 9.98			45.78 $\pm$ 20.41
NPK levels, RS$_1$							
0		33.47 $\pm$ 1.33		32.00 $\pm$ 2.00			25.04 $\pm$ 9.49
30		70.67 $\pm$ 2.05		43.33 $\pm$ 7.57			46.64 $\pm$ 26.83
60		74.66 $\pm$ 6.11		40.00 $\pm$ 2.00			60.33 $\pm$ 16.26
90		94.27 $\pm$ 3.25		58.00 $\pm$ 2.00			74.07 $\pm$ 22.27
Average		68.27 $\pm$ 23.18		43.33 $\pm$ 10.46			51.52 $\pm$ 26.14
NPK levels, RS$_2$							
0		16.60 $\pm$ 3.17		26.66 $\pm$ 4.61			21.63 $\pm$ 6.55
30		22.60 $\pm$ 7.87		32.66 $\pm$ 3.05			27.63 $\pm$ 7.67
60		46.00 $\pm$ 2.65		43.00 $\pm$ 6.55			44.50 $\pm$ 4.76
90		53.87 $\pm$ 2.21		43.03 $\pm$ 6.56			49.27 $\pm$ 5.57
Average		34.76 $\pm$ 16.72		36.75 $\pm$ 8.67			35.76 $\pm$ 13.07
Average NPK levels							
0		25.03 $\pm$ 9.49		29.33 $\pm$ 4.32			27.18 $\pm$ 7.38
30		46.63 $\pm$ 26.83		38.00 $\pm$ 7.79			42.32 $\pm$ 19.37
60		60.33 $\pm$ 16.25		41.50 $\pm$ 4.64			50.92 $\pm$ 15.05
90		74.07 $\pm$ 22.27		51.33 $\pm$ 7.66			62.70 $\pm$ 19.82
Average		51.51 $\pm$ 26.14		40.04 $\pm$ 9.97			45.77 $\pm$ 20.41
LSD	Y	RS	V	RS $\times$ Y	RS $\times$ V	V $\times$ Y	RS $\times$ Y $\times$ V
0.5	2.506	2.506	3.544	3.544	5.011	5.011	7.087
0.1	3.370	3.371	4.765	4.765	6.740	6.740	9.532

P—Parameter; NoSP—Number of seeds per plant; Y—Year; RS—Row spacing; V—Variant.

Table 11. ANOVA table for the number of seeds per plant.

Parameter	Number of Seeds per Plant				
Effect	SS	Deg. of Freed.	MS	F-Value	p-Value
Intercept	100,595.20	1	100,595.00	5544.72 **	0.00000
Row spacing—RS	4820.00	1	4820.00	265.676 **	0.00000
Year—Y	1580.10	1	1580.10	87.094 **	0.00000
Nutrition variant—V	8046.00	3	2682.05	147.830 **	0.00000
RS × Y	2173.50	1	2173.50	119.803 **	0.00000
RS × V	796.30	3	265.40	14.631 **	0.00000
Y × V	1313.50	3	437.80	24.132 **	0.00000
RS × Y × V	276.80	3	92.30	5.087 *	0.005420
Error	580.00	32	18.10		

SS—Sum of Squares; MS—Mean of Squares; * and **—Significant at the 0.05 and 0.01 probability level.

A significantly lower NoSP was obtained in the control variant (N_1 = 27) compared to the N_2—N_4 variants. The number of seeds increased with the increase in nutrients. A significantly higher number of seeds was obtained in variant N_4 compared to variant N_1 and N_2 ($p < 0.01$; Tables 10 and 11).

On the basis of the ANOVA, the row spacing, years, and nutrition had a highly significant influence on the NoSP ($p < 0.01$; F_{exp} = 265.676 **; F_{exp} = 87.094 **; F_{exp} = 147.830 **; respectively). There was a highly significant effect on the interaction of the tested factors; see Table 11.

Increasing density decreased the grains number per plant, while DM weight and yield displayed an acceleration first and then deceleration. The results of Xiang et al. (2016) suggested that planting density could alter the traits, resistance, and yield of buckwheat.

The findings of our research are also in line with those of Popovic et al. [19]. These authors stated that based on the ANOVA, row spacing and nutrition had a significant effect on the NoSP. A significantly lower NoSP was achieved at 50 cm row spacing and in the control variant compared to the variants with added nutrition. Depending on the row spacing, NoSP varied from 23 (50 cm) to 34 (25 cm).

3.1.5. Correlations between the Analyzed Traits

Grain yield was positive and highly correlated with NoSP, MSP, and variant and there was a positive significant correlation with plant height (PH), NoLB, and nonsignificant positive correlation with temperature (Table 12).

Table 12. Correlation of tested parameters of buckwheat, 2018–2019.

Parameter	PH	NoLB	NoSP	MSP	GY	V	RS	T	P
PH	1.00	0.54 *	0.43 *	0.44 *	0.30 *	0.72 *	0.24 ns	0.17 ns	−0.10 ns
NoLB	0.54 *	1.00	0.35 *	0.33 *	0.41 *	0.71 *	0.01 ns	−0.40 *	0.43 *
NoSP	0.43 *	0.35 *	1.00	0.69 *	0.81 *	0.62*	−0.50 *	0.28 ns	−0.26 ns
MSP	0.44 *	0.33 *	0.69 **	1.00	0.71 *	0.71 *	−0.26 ns	0.26 ns	−0.23 ns
GY	0.30 *	0.41 *	0.81 **	0.71 *	1.00	0.63 *	−0.65 *	0.19 ns	−0.17 ns

P—Parameter; PH—Plant height; NoLB—Number of lateral branches; NoSP—Number of seeds per plant; MSP—Mass of seeds per plant; GY—Grain yield; RS—Row spacing; V—Nutrition variant; T—Temperature; P—Precipitation; ns—Nonsignificantly correlated; * and **—Significantly correlated at 0.01 and 0.05.

The results indicated that the grain yield in all vegetation seasons was positive and highly correlated with NoSP (r = 0.81 **), MSP (r = 0.71 *), and variant (r = 0.63 *). The grain yield was positively and significantly correlated with plant height (r = 0.30 *) and NoLB (r = 0.41 *). Grain yield was nonsignificantly positive correlated with temperature (r = 0.19) and nonsignificantly negatively correlated with precipitation (r = 0.17) (Table 12).

Plant height in both seasons was positively and significantly correlated with nutrition variant (r = 0.72 **), NoLB (r = 0.54 *), NoSP (r = 0.43 **), MSP (r = 0.44 *), and grain yield (r = 0.30 *). Plant height was nonsignificantly positively correlated with temperature (r = 0.17) and nonsignificantly negatively correlated with precipitation (r = 0.10) (Table 12).

The mass of seeds per plant in both seasons was positively and significantly correlated with GY (r = 0.71 **), nutrition variant (r = 0.71 **), NoSP (r = 0.69 *), PH (r = 0.44 *), NoLB (r = 0.33 *), and nonsignificantly positively correlated with temperature (r = 0.26) and nonsignificantly negatively correlated with precipitation (r = 0.23) (Table 12).

The number of seeds per plant in both seasons was positively and high significantly correlated with GY (r = 0.81 **), nutrition variant (r = 0.62 *), MSP (r = 0.69 *), PH (r = 0.43 *), and NoLB (r = 0.35 *), and nonsignificantly positively correlated with temperature (r = 0.28). The number of seeds per plant was nonsignificantly negatively correlated with precipitation (r = 0.26) (Table 12).

The number of lateral branches in all seasons was positively and significantly correlated with the nutrition variant (r = 0.71 *), PH (r = 0.54 *), NoSP (r = 0.35 *), GY (r = 0.41 **), MSP (r = 0.33 *), precipitation (r = 0.43 *), and significantly negatively correlated with temperature (r = 0.43 *) (Table 12).

4. Discussion

The environment can have a crucial influence on plants' production in particular regions, even more so when production environments are different from optimum breeding environments [23,26,32,34]. The agro-meteorological conditions in 2010 were unfavorable for buckwheat production, which was primarily due to the poor distribution of precipitation and large temperature fluctuations during fertilization, which led to lower yields for the area [35].

Variations in the temperature and in the amount of precipitation during vegetation of buckwheat as well as in the moisture content in the soil are the most important factors of the instability of the yield [3,20,36]. Martinez et al. [37] emphasize that in the favorable productive years, yield was the highest in the conventional tillage compared with the no-tillage system. Maksimovic et al. [32] state that beside the choice of cultivar and proper agro-technical practices, buckwheat production is considerably affected by soil and climatic conditions. In dry conditions, the lack of water affects the nutrient supply of plants. The transport of nutrients to actively growing branches and flower buds is reduced, which in turn lowers grain yield and quality.

One of the plant's basic elements is N. Buckwheat response to N depends on the total N content of the soil, climatic conditions, and N additives as well as its addition timing [34].

The supplementary nutrition of buckwheat plants increases grain yield [2,19], and the system of applied production technology (time and method of sowing) can increase the production productivity [5]. Nitrogen nutrition is an important yield-creating factor for buckwheat because it increases grain yield as well as the protein content in grains [38].

The increase in N can enhance biomass, leaf area, number of branches, and quantitative and qualitative grain yields. The influence of row spacing, plant density, and N nutrition on the number of branches and protein content increase has been observed [15,39].

At a row spacing of 50 cm, buckwheat encountered competition with weeds *Ambrosia artemisifolia* and *Cirsium* sp., which resulted in a significantly lower grains yield; see Table 1. Similar results were obtained by Nozinic [21]. The optimal number of plants provides greater tolerance to adverse weather conditions [21].

Nozinic [21] points out that in a trial with three row spacings (12.5, 25, and 50 cm), planting density was in complete correlation with yield. The highest buckwheat grain yield of 2.43 t ha^{-1} was for 25 cm row spacing, while the yields were 1.54 and 1.53 t ha^{-1} respectively for 15 cm and 50 cm. A planting rate of 12.5 cm caused crop lodging, and a rate of 50 cm caused more intensive development of weeds than of buckwheat.

Our data indicated significant positive correlations between plant height and total seed weight. Arshad et al. [40] reported significant positive correlations of grain yield

with plant height. In gramineous crop plants, a taller stature is usually associated with higher yield.

The pattern of planting influenced the percentage of fat, seed yield, and the number of leaves in the plant. The sowing date influenced the percentage of protein, fat, and starch in the seed, the seed yield, the number of leaves in the plant, the thickness of the stem, and the height of the plant; the amount of nitrogen affected the percentage of protein and starch, seed yield, and the number of the leaves. Concerning the dual mutual effects, the pattern of planting and nitrogen influenced the percentage of protein, starch, and seed yield. The sowing date and nitrogen together influenced the percentage of protein, fat, starch, and seed yield. The pattern of planting and the sowing date influenced the percentage of protein, seed yield, and the number of the leaves. Regarding the triple mutual effects of sowing date × the pattern of planting × nitrogen, these three factors greatly influenced the amount of fat, starch, and protein, seed yield, and the number of leaves [41]. Özyazici [42] states that N doses had significant effects on seed yield, while some of the agricultural properties affected the yield and protein ratio. According to N doses, the plant height, branch number, number of leaves, number of inflorescence, biological yield, seed yield, thousand seed weight, and protein ratio were ranged within 63.00–71.50 cm, 3.28–5.00 number plant^{-1}, 19.25–31.00 number plant^{-1}, 12.75–23.50 number plant^{-1}, 3611.0–9936.0 kg ha^{-1}, 588.0–1492.0 kg ha^{-1}, 19.39–23.52 g, and 10.72–13.65%, respectively. It was concluded that 114.8 kg ha^{-1} nitrogen can be applied in terms of seed yield in buckwheat cultivation in soils with low organic matter content.

Yokozawa et al. [43] reported that buckwheat polyphenol extract has a beneficial effect on patients with renal problems. The effect was probably due to the content of rutin, quercetin, hyperosid, and phenolic oligomers of buckwheat. The diversity of the antioxidative effect was connected to the interaction of genetic and environmental factors in buckwheat [44]. Rutin prevents capillary fragility and high blood pressure [44,45]. As reported by authors [46], more rutin is synthesized at higher temperature (24.5 °C daytime and 18 °C at night) in comparison to lower temperature (18 °C daytime and 12 °C at night). The highest amounts of rutin were contained in the upper epidermis, and glycosidase was the most active in the lower epidermis. Wagenbreth et al. [47] found a variable rutin content (2% to 9%, d.m.b. dry matter basis) in the leaves of different buckwheat cultivars. In leaves situated higher on the plant, there was more rutin than in the lower ones. They found the highest rutin content in the inflorescences (up to 12%, d.m.b.).

Buckwheat is a nutritionally valuable crop that is an alternative to common cereals andalso usable in gluten-free diets. The selection of buckwheat genotypes suitable for further breeding requires the characterization and evaluation of genetic resources [48]. Significant differences among years and genotypes were observed for morphological traits [49,50]. Due to the great nutritional value of buckwheat, certification should be worked on as well as branding buckwheat products, because buckwheat has a significant place in programs of integral and organic production systems.

Crop management can significantly influence buckwheat yield, rutin, starch, and protein content [51]. The nutritive value of buckwheat seeds is much higher than that of cereal crops. Buckwheat is a green functional food. The buckwheat proteins are particularly rich in lysine and contain less glumatic acid and proline than cereal proteins as well as more arginine and aspartic acid. Buckwheat proteins also show a strong supplemental effect with other proteins to improve the dietary amino acid balance with special biological activities of cholesterol-lowering effects, antihypertension effects, and improving the constipation and obesity conditions by acting in a similar way as dietary fiber and interrupting the in vivo metabolisms. In addition to its high-quality proteins, buckwheat is also rich with flavones, flavonoids, phytosterols, D-chiro-inositol, and myo-inositol [50]. The protein content in buckwheat is approximately 12%, the fat content is about 3%, the crude fiber concentration is 15.8%, the carbohydrates content is 48.7%, and the tannin content is 1.76%. The protein quality is very high, with a biological values above 90%. Buckwheat is rich in polyphenols, including six flavonoids: rutin, orientin, vitexin, quercetin, isovitexin, and

isoorientin. Among these antioxidant components, rutin was recognized as the most health protective and has also been proven to be anti-inflammatory and anticarcinogenic [5,52].

5. Conclusions

The method proposed by the present study for the evaluation of the effect of nutrition on buckwheat and row spacing was practical and efficient. Buckwheat grain yield was strongly dependent on row spacing, NPK nutrition, and weather conditions during the study years. Seed yield was significantly influenced by row spacing (RS), year (Y), and nutrition variant (V), as well as the interaction of tested factors, V × Y, Y × RS, and RS × V. In 2018, there was a significantly higher seed yield. At a narrower row spacing, a significantly higher seed yield was achieved. Buckwheat grain yield was significantly positively correlated with the number of seeds per plant, mass of seeds per plant, and nutrition variant; and it was significantly positively correlated with plant height and the number of lateral branches and nonsignificantly positively correlated with temperature. The maximum grain productivity in a field experiment with buckwheat 'Novosadska' can be obtained at 90 kg ha^{-1} NPK. The wide–narrow row spacing and nutrition are recognized as good management practices in crop production. Optimizing row spacing and nutrition for maximum profitability is of great importance in the future buckwheat production in Pannonian environments.

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

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