ISSN 2226-3063 e-ISSN 2227-9555
Modern Phytomorphology **12**: 73–79, 2018

https://doi.org/10.5281/zenodo.1295697

CORRESPONDENCE

Yield components of haricot beans (*Phaseolus vulgaris* L.) depending on cultivation technology elements at the irrigated lands of the Steppe zone

Viktor O. Ushkarenko [1], Sergiy O. Lavrenko [1], Pavlo V. Lykhovyd [2]*, Nataliia M. Lavrenko [1], Dmytro O. Maksymov [1]

[1] Kherson State Agricultural University, Stritenska str. 23, 73006 Kherson, Ukraine

[2] Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, 73483 Naddniprianske, Kherson, Ukraine; * pavel.likhovid@gmail.com

Received: 13.04.2018 | **Accepted**: 04.06.2018 | **Published**: 21.06.2018

Abstract

Phaseolus vulgaris (haricot beans) is one of the most important pulse crops with high nutritive and strategic value. The goal of our study was to define changes in morphological elements playing the crucial role in crop productivity, namely, in the yield components (number of the pods and seeds per plant) depending on the cultivation technology treatments. We studied effects of moldboard plowing depth, mineral fertilizers application doses and inter-row spacing on the above-mentioned haricot beans yield components in conditions of the Steppe zone in field trials. The trials were carried out at the irrigated lands represented by the dark-chestnut solonets soil, in four replications by using the split plot design method with partial randomization during the period of 2014–2016. The data obtained in the trials were processed by using ANOVA and correlation analysis. Results of the study showed significant increase in the number of pods and seeds per plant of haricot beans with decrease of inter-row spacing width and higher mineral fertilizers application doses. Depth of plowing had no significant effect on the number of pods, and slightly effected the number of seeds per plant of haricot beans. The maximum number of pods (17.2) and seeds (71.7) per plant of the crop was provided by the agrotechnical complex with moldboard plowing at the depth of 28–30 cm, mineral fertilizers application dose of $N_{90}P_{90}$, and inter-row spacing of 15 cm.

Keywords: *Phaseolus vulgaris*, haricot beans, yield components, cultivation technology, Steppe zone

Introduction

Phaseolus vulgaris L. (haricot beans) is an annual pulse crop, which has a lot of different morphological and biological variations in features depending on genotype (Omwueme & Sinha 1999). It is likely to be originated in America, but nowadays haricot beans are among the most important pulse crops widely cultivated throughout the world (Graham & Ranalli 1997). For example, in Africa, particularly in Ethiopia, it is a highly valuable cash crop (Turuko & Mohammed 2014). This crop has very high nutritive value as a source of starch, protein, different vitamins and micro nutrients, etc. It is used in cooking of various dishes, which are not only good for health, but delicious too. So, haricot beans are the crop of food security, especially, in the modern conditions of malnutrition.

Haricot beans are interesting not only for their nutritive value. This crop can be used for phytoremediation of the irrigated and non-irrigated soils, what is related to its facilities to fix and accumulate Nitrogen (Chandra et al. 1987; Dhatonde & Nalamwar 1996). So, at the moment, haricot beans are of an interest to the international community. The cultivation technology is carefully studied and improved (Jaiswal et al. 1997). Besides, agro-industrial progress is going on, and climate is changing either (Lykhovyd 2018). To deal with modern challenges that did not occur before, agricultural science specialists shall gain new knowledge of the crop biology and adjust its cultivation technology to its biological requirements, also taking into account concrete productive conditions. The goal of our study was to improve cultivation technology of haricot beans grown at the irrigated lands of the Steppe zone in modern agricultural, industrial and climatic conditions.

Material and methods

The field trials devoted to the improvement of haricot beans cultivation technology were carried out at the irrigated lands of the Agricultural Cooperative Farm "Radianska Zemlia", situated in the Bilozerskii district, Kherson region, Ukraine (46°42'24.90" N, 32°16'27.77" E, 37 m a.s.l.). The experiments and investigations were put on by using the split plot design method with partial randomization in four replications within 2014–2016.

The field trials were held on at the dark-chestnut solonets soil. Humus content in the 0–50 cm soil layer was 2.5%. Depth of the humus horizon was 50–55 cm. Bulk density of the 0–100 cm soil layer was 1.35 $t \cdot m^{-3}$; bulk density of the solid soil fraction – 2.66 $t \cdot m^{-3}$; total porosity of the soil – 49–50%. Content of the lightly-hydrolyzed Nitrogen determined by Kornfield was 35 $mg \cdot kg^{-1}$; content of the mobile Phosphorus determined by Machygin – 32 $mg \cdot kg^{-1}$; content of the exchangeable Potassium determined by Machygin – 430 $mg \cdot kg^{-1}$ in the studied soil layer. Power of Hydrogen in the upper soil layer was neutral (pH 7.0), with tendency to increase the pH in deeper layers up to 7.4–7.9. Ground waters of Sulphate-Chloride type were slightly saline with total dissoluble salts content averaged to 1–3 $g \cdot L^{-1}$; they are deep enough (at the depth of more than 5 m) and do not effect crop production. All the above-mentioned data were obtained from the results of agrochemical inspections of the fields of the basic farm.

Meteorological conditions of the studied period are represented in the Tab. 1. According to these data, the hottest year was 2016, the wettest one was 2015, and the most unfavorable weather conditions concerning to haricot beans cultivation were observed in 2014, which was the driest year

Table 1. Meteorological conditions within the period of haricot beans cultivation in the field trials. Long-term means are given for the period of 1986–2005.

Month	Decade	Air temperature, °C				Relative humidity, %				Precipitation amounts, mm			
		2014	2015	2016	Monthly long-term mean	2014	2015	2016	Monthly long-term mean	2014	2015	2016	Monthly long-term mean
March	I	5.5	3.6	7.8		83	79	85		0.0	10.9	9.4	
	II	7.8	5.4	4.3	2.3	60	79	71	77	0.0	23.1	0.3	26.0
	III	8.8	6.3	6.8		67	76	77		32.0	19.8	9.4	
Monthly		7.4	5.2	6.3		70	78	78		32.0	53.8	19.1	
April	I	7.6	5.7	11.3		60	77	63		0.0	52.9	1.2	
	II	12.4	10.9	14.3	10.0	74	72	77	69	29.2	2.5	45.5	33.0
	III	14.5	11.3	12.3		63	72	74		0.3	10.1	10.1	
Monthly		11.5	9.3	12.6		65	73	71		29.5	65.5	56.8	
May	I	13.7	13.9	14.5		75	77	72		33.0	13.7	12.7	
	II	17.8	17.4	15.3	16.0	75	62	79	64	5.2	2.5	38.3	42.0
	III	22.2	19.6	18.5		61	69	77		0.0	70.7	20.7	
Monthly		18.0	17.0	16.2		70	69	76		38.2	86.9	71.7	
June	I	22.4	21.3	17.8		64	61	70		13.3	7.1	16.2	
	II	20.0	21.3	21.9	19.9	58	67	75	67	28.6	3.4	12.8	45.0
	III	20.0	20.0	26.5		64	73	62		22.5	27.8	14.0	
Monthly		20.8	20.9	22.1		62	67	69		64.4	38.3	43.0	
July	I	23.5	22.8	22.4		53	74	61		0.0	84.9	21.6	
	II	25.5	21.0	25.8	21.9	56	66	59	61	9.4	19.7	0.0	49.0
	III	26.1	26.0	25.0		49	67	54		10.0	0.0	24.7	
Monthly		25.1	23.4	24.4		52	69	58		19.4	104.6	46.3	
August	I	27.8	26.0	26.0		45	49	55		11.1	0.0	0.6	
	II	25.1	23.8	23.3	21.3	57	54	58	62	0.8	12.1	0.0	38.0
	III	21.0	22.9	24.7		56	46	62		8.8	0.0	26.1	
Monthly		24.5	24.2	24.7		52	49	59		20.7	12.1	26.7	

of the studied period. All the meteorological observations were held at the Kherson Regional Hydro-Meteorological Station.

Scientific program of the investigations included study of such cultivation technology elements: Factor A – moldboard plowing depth (20–22 and 28–30 cm), Factor B – mineral fertilizers application doses (no fertilizers applied; $N_{45}P_{45}$; $N_{90}P_{90}$ of active substance applied in kg·ha^{-1}), Factor C – inter-row spacing (15, 30, 45, and 60 cm). Components of haricot beans yield, i.e. number of pods and number of seeds per plant, were determined by the direct counting. Haricot beans cultivation technology in the trials was based on the common recommendations for the irrigated conditions of the Steppe zone. The fore-crop was winter wheat. Double stubble harrowing at the depth of 6–8 and 10–12 cm followed by the moldboard plowing at the planned depths was conducted after the harvesting of previous crop. Mineral fertilizers (ammonium nitrate and superphosphate) were applied with accordance to the experimental design before plowing by the means of seed drill. Soil cultivation at the depth of 12–14 cm was conducted in a fortnight to destroy weeds and level ground surface. In early spring the soil was dragged. Pre-sowing cultivation was carried out at the depth of sowing. Haricot beans were sown at the depth of 5–7 cm with inter-row spacing according to the experimental design. The sowing rate was 0.4 million per ha. The seeds were treated with biological preparations of highly efficient species of micorrhizal Nitrogen-fixing bacteria. The terms of sowing were: 8th of April in 2014, 17th of April in 2015 and 5th of April in 2016. Herbicide Hezaguard 500 FW (*Prometryn*, 500 g · L^{-1} of the active substance) was applied at pre-sprouting period in the dose of 3.0 L · ha^{-1}. Insecticide Nurel D (*Chlorpyrifos*, 500 g · L^{-1} and *Cypermethrin*, 50 g · L^{-1} of the active substance) was applied at the budding-flowering stage in the dose of 1.0 L · ha^{-1}. The crops were treated with Rehlon Super 150SL desiccate (*Diquat ion*, 150 g · L^{-1} of the active substance) in the dose of 2.0 L · ha^{-1} before harvesting. Harvesting was conducted by the means of self-propelled combine harvester on the 23rd of July in 2014, 6th of August in 2015 and 25th of July in 2016.

Soil moisture in the layer of 0–50 cm during the crop growth and development was maintained at the level of 75–80 % of the field water-holding capacity by the means of sprinkler overhead irrigation. The total volumes of the irrigation water applied were 1450 m^3 · ha^{-1} in 2014, 1000 m^3 · ha^{-1} in 2015 and 1350 m^3 · ha^{-1} in 2016. The Inhulets irrigation system (47°00'49.41" N, 32°47'19.18" E, 51.76 m a.s.l.) was the source of water for irrigation. The water is unfavorable for irrigation because of high content of total dissoluble salts (1448–1578 mg · L^{-1}), toxic ions (10.42–12.22 in eCl$^-$), sodium adsorption ratio (4.79–5.78 me · L^{-1}), etc. (Likhovid 2015; Lykhovyd & Kozlenko 2018). This fact should be taken into account under estimation of biological processes in plants and soils (Lykhovyd & Lavrenko 2017).

The data collected within the trials were processed using the multi-factor analysis of variance (ANOVA) with accordance to the standard common methodology (Rosner 2006; Kim 2014). The least significant difference (LSD) was calculated at $p < 0.05$.

Standard deviation (SD) of the studied indexes was calculated by using the Formula 1 (Furness & Bryant 1996; Logan 2011):

$$SD = \frac{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2}}{N-1} \text{, where} \qquad (1)$$

SD – the standard deviation;
$\bar{x}$ – the mean value of the observed index;
x_i – the values of the studied indexes;
N – the number of the observations.

We used the coefficient of determination (R^2) values for estimation of relationships between yield components (Formula 2, Devore 2011):

$$R^2 = 1 - \frac{V(y|x)}{V(y)} \text{, where} \qquad (2)$$

$V(y|x)$ – the dispersion of the dependent argument;
x – the values of the explanatory variable;
y – the values of the dependent variable.

Table 2. Average number of pods per plant of haricot beans depending on moldboard plowing depth, mineral fertilizers doses and inter-row spacing in the field trials (studied in four replications). Mean ± SD.

Moldboard plowing depth, cm (Factor A)	Mineral fertilizers application doses (Factor B)	Inter-row spacing, cm (Factor C)				Average values of the index
		15	30	45	60	
20–22	No fertilizers	13.9 ± 1.1	12.5 ± 0.8	11.1 ± 0.7	10.3 ± 0.5	12.0 ± 0.8
	$N_{45}P^{45}$	16.8 ± 0.6	13.7 ± 1.2	12.7 ± 0.7	11.9 ± 1.1	13.8 ± 0.9
	$N_{90}P_{90}$	17.0 ± 1.1	14.4 ± 1.0	13.7 ± 0.7	12.9 ± 0.7	14.5 ± 0.9
Average values of the index		15.9 ± 0.9	13.5 ± 1.0	12.5 ± 0.7	11.7 ± 0.8	13.4 ± 0.9
28–30	No fertilizers	14.1 ± 1.1	12.7 ± 0.8	11.3 ± 0.6	10.4 ± 0.4	12.1 ± 0.7
	$N_{45}P^{45}$	16.9 ± 0.6	13.9 ± 1.2	12.9 ± 0.8	12.1 ± 1.1	14.0 ± 0.9
	$N_{90}P_{90}$	17.2 ± 1.1	14.6 ± 1.0	13.9 ± 0.7	13.0 ± 0.7	14.7 ± 0.9
Average values of the index		16.1 ± 0.9	13.7 ± 1.0	12.7 ± 0.7	11.8 ± 0.7	13.6 ± 0.8

Note. LSD at $p < 0.05$ for each of the studied factors: **A** – 0.32; **B** – 0.39; **C** – 0.45. LSD at $p < 0.05$ for the interaction of the studied factors: **AB** – 0.55; **AC** – 0.63; **BC** – 0.78. LSD at $p < 0.05$ for the combined interaction of all the studied factors: **ABC** – 1.10.

Results

The main yield components of haricot beans are the number of pods and the number of seeds per plant. Haricot beans productivity is considered to be mainly effected by these two indexes. The higher they are, the higher yielding capacity of the crop is.

The study showed an insignificant impact of the moldboard plowing depth on the average number of pods per plant of haricot beans: difference between the depths of 20–22 cm and 28–30 cm (averaged to 0.2 pods) was estimated to be less than the LSD values (0.26–0.42 pods). And effect of the mineral fertilizers was considerable enough. All the differences between the studied treatments were significant at $p < 0.05$. Application of the mineral fertilizers in dose of $N_{45}P_{45}$ resulted in average increase of the pods number per plant up to 15.35% (1.85 pods more per plant), and when the dose was raised up to $N_{90}P_{90}$ productivity increase averaged up to 21.16% (2.55 pods more per plant) comparatively to non-fertilized trial's variant. The inter-row spacing also effected the number of haricot beans pods setting per plant, and impact of the factor was really crucial. The highest number of pods per plant was observed at the treatments with the inter-row spacing of 15 cm (16.0 pods), that was 36.17% (4.25 pods) more than at the treatment with the worst index under the inter-row spacing of 60 cm (11.75 pods). All the differences between the treatments with various inter-row spacing were significant at $p < 0.05$ (Tab. 2).

Similar tendencies were established studying the number of seeds per plant of haricot beans. We found that increase of the depth of moldboard plowing up to 28–30 cm just slightly improved crop productivity (up to 1.06 seeds or 2.69%), but it should be mentioned that this increase was significant (LSD at $p < 0.05$ was 0.83–0.99). The most drastic factor remained inter-row spacing – the difference between the best (15 cm) and the worst (60 cm) treatments was 23.84% (12.60 seeds per plant). And the next place was occupied by the mineral fertilizers doses that are considered to be helpful and increased the crop productivity up to 20.97%

Table 3. Average number of seeds per plant of haricot beans depending on moldboard plowing depth, mineral fertilizers doses and inter-row spacing in the field trials (studied in four replications). Mean ± SD.

Moldboard plowing depth, cm (Factor A)	Mineral fertilizers application doses (Factor B)	Inter-row spacing, cm (Factor C)				Average values of the index
		15	30	45	60	
20–22	No fertilizers	56.5 ± 1.9	55.9 ± 2.3	52.8 ± 1.8	46.0 ± 1.3	52.8 ± 1.8
	$N_{45}P^{45}$	67.6 ± 2.8	65.2 ± 2.1	61.1 ± 1.4	52.4 ± 1.3	61.6 ± 1.9
	$N_{90}P_{90}$	70.3 ± 3.7	66.6 ± 2.9	63.3 ± 2.0	55.1 ± 1.8	63.8 ± 2.6
Average values of the index		64.8 ± 2.8	62.6 ± 2.4	59.1 ± 1.7	51.2 ± 1.5	59.4 ± 2.1
28–30	No fertilizers	56.9 ± 2.9	56.3 ± 2.1	53.2 ± 1.7	49.5 ± 1.5	54.0 ± 2.1
	$N_{45}P^{45}$	69.6 ± 2.3	66.7 ± 2.1	62.0 ± 2.2	56.5 ± 1.5	63.7 ± 2.0
	$N_{90}P_{90}$	71.7 ± 4.2	68.1 ± 1.6	64.1 ± 1.4	57.6 ± 1.6	65.4 ± 2.2
Average values of the index		66.1 ± 3.1	63.7 ± 1.9	59.8 ± 1.8	54.5 ± 1.5	61.0 ± 2.1

Note. LSD at $p < 0.05$ for each of the studied factors: **A** – 0.92; **B** – 1.13; **C** – 1.30. LSD at $p < 0.05$ for the interaction of the studied factors: **AB** – 1.59; **AC** – 1.84; **BC** – 2.25. LSD at $p < 0.05$ for the combined interaction of all the studied factors: **ABC** – 3.19.

(up to 11.20 seeds per plant). Seed yields per haricot beans plant are represented in the Tab. 3.

So, the results gave us an opportunity to conclude that the highest productivity of the crop can be achieved under the cultivation with moldboard plowing at the depth of 28–30 cm, mineral fertilizers application dose of $N_{90}P_{90}$ and inter-row spacing of 15 cm. The interaction of these three factors significantly improved pods and seeds yields of haricot beans in the study. Besides, strong dependence of haricot beans pods and seeds yields was determined (coefficient of determination R^2 was 0.81).

Discussion

Matching our results to the results of other scientists, we found some common and some contraversary points. We are not the first to discover increase in productivity of haricot beans concerning to growing the crop under the narrower inter-row spacing. The study conducted at Lincoln in 1969–1970 had established significant yield increase up to 9.8% in the crops with 2 inches (5 cm) inter-row spacing comparatively to 4 inches (10 cm) one (Fininsa 1997), the tendency we confirmed in our study. Besides, significant increase in yielding and yield components, particularly in the number of pods per plant of haricot beans, with decrease in inter-row spacing to 4.8 cm was proved by earlier researches (Goulden 1976). Also, there are many studies reporting considerable productivity and yield components increase of haricot beans concerning to application of higher doses of mineral fertilizers (Abebe 2009; Turuko & Mohammed 2014). But recommended doses of mineral fertilizers are quite different. For example, in Ethiopia it is recommended to use $N_{60}P_{10–30}$ mineral fetilizers doses (Gidago et al. 2011; Turuko & Mohammed 2014), while we determined the best crop performance at the level of $N_{90}P_{90}$. These distinctions we put down to the difference in soil, climate and agro-industrial conditions of the studied areas. We should mention that there are no scientifically grounded studies in questions of tillage effects on haricot beans, so we were one of the first to raise this problem and provide substantiated solution about primary tillage depth.

Conclusions

The highest numbers of pods (17.2) and seeds (71.7) were obtained under the interaction of such agricultural treatments as moldboard plowing at the depth of 28–30 cm, mineral fertilizers application dose of $N_{90}P_{90}$ and inter-row spacing of 15 cm. We consider that the above-mentioned agrotechnical complex should be recommended to agricultural producers, which are going to grow haricot beans at the irrigated lands of the Steppe zone. We cannot avoid mentioning the fact of low inputs of the plowing depth increase into the crop productivity of haricot beans. Realizing all the limitations of our study, we do recommend keeping on researches in this field, and we are going to carry out further investigations in the nearest future to obtain more comprehensive results.

References

Abebe G. 2009. Effect of NP fertilizer and moisture conservation on the yield and yield components of haricot bean (*Phaseolus vulgaris* L.) in the semi-arid zones of the Central Rift Valley in Ethiopia. *Adv. Environ. Biol.* **3 (3)**: 302–307.

Chandra R., Rajput C.B.S., Singh K.P., Singh S.J.P. 1987. A note on the effect of nitrogen phosphorus and *Rhizobium* culture of the growth and yield of French bean (*Phaseolus vulgaris* L.) cv. *Contender*. *Haryana J. Hort. Sci.* **16**: 146–147.

Devore J.L. 2011. Probability and statistics for engineering and the sciences. Cengage learning, Boston.

Dhatonde B.N., Nalamwar R.V. 1996. Effect of nitrogen and irrigation levels on yield and water use of French bean (*Phaseolus vulgaris*). *Ind. J. Agron.* **41 (2)**: 265–268.

Fininsa C. 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean / maize intercrop. *Afr. Crop Sci. J.* **5 (1)**: 15–22. https://doi.org/10.1080/00288233.1971.10421318

Furness R.W., Bryant D.M. 1996. Effect of wind on field metabolic rates of breeding northern fulmars. *Ecology* **77 (4)**: 1181–1188.

Gidago G., Beyene S., Worku W., Sodo E. 2011. The response of haricot bean (*Phaseolus vulgaris* L.) to phosphorus application on Ultisols at Areka, Southern Ethiopia. *J. Biol., Agri. Healthcare* **1 (3)**: 38–49.

Goulden D.S. 1976. Effects of plant population and row spacing on yield and components of yield of navy beans (*Phaseolus vulgaris* L.). *New Zeal. J. Exp. Agri.* **4 (2)**: 177–180. https://doi.org/10.1080/03015521.1976.10425865

Graham P.H., Ranalli P. 1997. Common bean (*Phaseolus vulgaris* L.). *Field Crops Res.* **53 (1–3)**: 131–146. https://doi.org/10.1016/S0378-4290(97)00112-3

Jaiswal H.K., Singh U.P., Singh O.N., Rai B. 1997. Technological basis for increasing production of french bean in plains. *Indian Farming* **47 (1)**: 15–18.

Kim H.-Y. 2014. Analysis of variance (ANOVA) comparing means of more than two groups. *Restor. Dent. Endod.* **39 (1)**: 74–77. https://doi.org/10.5395/rde.2014.39.1.74

Likhovid P.V. 2015. Analysis of the Ingulets irrigation water quality by agronomical criteria. Success of Modern Science and Education 5: 10–12.

Logan M. 2011. Biostatistical design and analysis using R: A practical guide. John Wiley & Sons.

Lykhovyd P.V. 2018. Global warming inputs in local climate changes of the Kherson region: Current state and forecast of the air temperature. *Ukr. J. Ecol.* **8 (2)**: 39–41. https://doi.org/10.15421/2018_307

Lykhovyd P.V., Kozlenko Ye.V. 2018. Assessment and forecast of water quality in the River Ingulets irrigation system. *Ukr. J. Ecol.* **8 (1)**: 350–355. https://doi.org/10.15421/2018_221

Lykhovyd P.V., Lavrenko S.O. 2017. Influence of tillage and mineral fertilizers on soil biological activity under sweet corn crops. *Ukr. J. Ecol.* **7 (4)**: 18–24. https://doi.org/10.15421/2017_81

Omwueme I.C., Sinha T.D. 1999. Field crop production in Tropical Africa. CTA, Wageningen, Netherlands.

Rosner B. 2006. Fundamentals of biostatistics. Duxbury Press, Belmont, CA.

Turuko M., Mohammed. A. 2014. Effect of different phosphorus fertilizer rates on growth, dry matter yield and yield components of common bean (*Phaseolus vulgaris* L.). *World J. Agri. Res.* **2 (3)**: 88–92. https://doi.org/10.12691/wjar-2-3-1