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Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank Forest-Steppe in Ukraine

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We presented the analysis of agroecological factors, which provides development of regulations in the application of alternative fertilizers for soybean cultivation with short-term and long-term action. To establish the reliability of yield data by analysis of variance, it was determined that $LSD_{0.05}$ for factor A in 2017 was 0.09 t/ha. The largest deviations of yield indicators to control among varieties were: variety Podilska416 –0.41 t/ha, variety Chernivtsi9 – 0.27 t/ha and variety Agate – 0.66 t/ha, which exceeded the value of $LSD_{0.05}$ for the factor A (soybean variety) by 0.32, 0.18 and 0.57 t/ha, respectively.

Keywords: Agroecological factors; Bioorganic varietal; Technology; Soybean; Cultivation

Introduction

The increase in soybean production in all growing zones is due to both the expansion of sown areas and, very importantly, the increase in its yield. However, as reported, A.V. Semtsov and A.O. Babich, the selection of a variety is of great importance in increasing the yield and improving the quality of soybean seeds. But, as noted by Myakushko Y., Baranov V., soybean varieties have a narrow ecological adaptation, so the technology of growing this crop should be based on the best, most adapted to the specific soil and climatic conditions of the zone, zoned and promising varieties of local selection. Academician A.O. Babich points out that for each soil-climatic zone a whole group of varieties is well zoned, well adapted to the conditions of the regions, they ripen reliably, provide high yields. At the same time, the author believes that the main areas of soybeans in the Forest-Steppe and Steppe should be occupied by medium-early and medium-ripe varieties that would effectively use the entire growing season. However, A.O. Babych and Petrichenko V.F. emphasize that it would be a mistake to think that soybeans can be grown everywhere in Ukraine. High soybean yields are possible only within the so-called soybean belt, outside of which its production without irrigation is risky, especially in the arid southeastern and southern regions. From the perspective, this strategic crop can be sown on a fairly large area of the right-bank and left-bank Forest-Steppe, Northern, Central and South-Western Steppe, Forest Steppe areas of Polissya and irrigated lands of the Southern Steppe. The creation of a soybean belt will mean a new stage in the production of soybean crops, will promote the biologization of agriculture, the production of environmentally friendly products. The basis of the soybean belt is varietal zoning and bioclimatic resources of the region.

There are no secondary measures in soybean cultivation technology. Any agronomic measure is important and necessary in its own way. Its influence on the final result – yield, can be manifested to a greater or lesser extent, depending on the growing conditions.In this regard, there is a need to study the competitive relationship in soybean agrobiocenoses as a factor that can be regulated by elements of varietal cultivation technology. To date, in the agricultural sciences, multidimensional analysis is given insufficient attention, so in our research, we decided to pay special attention to this. Cluster analysis is most often used in agronomic research. Unlike many other procedures, cluster analysis is used when the researcher does not have certain a priori hypotheses about the overall assescment of research options. The concept of cluster analysis is to determine the optimal value of the objective function among the initial set. Most clustering algorithms are based on the use of heuristic methods, so their choice is to obtain the most useful result.

Materials and Methods

Studies on the optimization of varietal agricultural techniques of soybean cultivation were carried out by establishing a field experiment in accordance with the generally accepted method of three-factor scheme in four repetitions. The sown area of the elementary plot was 29.16, the accounting area was 25 m^2. The aim of the research was to study the influence of varieties, fertilizer rates and sowing methods on soybean yield.

Results and Discussion

Table 1. Significance of the influence of variety, norms of mineral fertilizers and sowing method on soybean yield in 2017.

A	C	B	Option number	Option code	$\bar{x}$	The difference in factors A	C	B	LSD$_{0.05}$	S$\bar{x}$ %
		Control	1	0	1.75	-	-	-		
	15 cm	P60K30 + (N15)	2	B	1.68	-	-	-0.07		
		N30P60K30 + (N15)	3	B1	2.41	-	-	0.66		
		N45P60K30 + (N15)	4	B2	2.59	-	-	0.84		
Podilsa 1		without fertilizers	5	C	2.52	-	0.77	-		
	45 cm	P60K30 + (N15)	6	BC	2.99	-	1.31	0.47		
		N30P60K30 + (N15)	7	B1C	2.71	-	0.3	0.19		
		N45P60K30 + (N15)	8	B2C	2.93	-	0.34	0.41		
		without fertilizers	9	A	1.70	-0.05	-	-		
	15 cm	P60K30 + (N15)	10	AB	1.61	-0.07	-	-0.09		
		N30P60K30 + (N15)	11	AB1	2.20	-0.21	-	0.5		
		N45P60K30 + (N15)	12	AB2	2.66	0.07	-	0.96		
Podilska 416		without fertilizers	13	AC	2.93	0.41	1.23	-		
	45 cm	P60K30 + (N15)	14	ABC	3.22	0.23	1.61	0.29		
		N30P60K30 + (N15)	15	AB1C	2.74	0.03	0.54	-0.19		
		N45P60K30 + (N15)	16	AB2C	2.85	-0.08	0.19	-0.08	0.27	3.96
		without fertilizers	17	A1	1.67	-0.08	-	-		
	15 cm	P60K30 + (N15)	18	A1B	1.62	-0.06	-	-0.05		
		N30P60K30 + (N15)	19	A1B1	2.15	-0.26	-	0.48		
		N45P60K30 + (N15)	20	A1B2	2.44	-0.15	-	0.77		
Chernivetska 9		45 cm	21	A1C	2.69	0.17	1.02	-		
	45 cm	P60K30 + (N15)	22	A1BC	3.05	0.06	1.43	0.36		
		N30P60K30 + (N15)	23	A1B1C	2.44	-0.27	0.29	-0.25		
		N45P60K30 + (N15)	24	A1B2C	2.71	-0.22	0.27	0.02		
		without fertilizers	25	A2	1.74	-0.01	-	-		
	15 cm	P60K30 + (N15)	26	A2B	1.62	-0.06	-	-0.12		
		N30P60K30 + (N15)	27	A2B1	1.75	-0.66	-	0.01		
		N45P60K30 + (N15)	28	A2B2	2.38	-0.21	-	0.64		
Agate		without fertilizers	29	A2C	2.43	-0.09	0.69	-		
	45 cm	P60K30 + (N15)	30	A2BC	2.74	-0.25	1.12	0.31		
		N30P60K30 + (N15)	31	A2B1C	2.40	-0.31	0.65	-0.03		
		N45P60K30 + (N15)	32	A2B2C	2.66	-0.27	0.28	0.23		
LSD0.05 for factors A, B, C			0.09	0.09	0.07					

In agricultural research, cluster analysis is most often used in breeding and crop. To establish the reliability of yield data by analysis of variance, it was determined that LSD$_{0.05}$ for factor A in 2017 (Table 1) was 0.09 t/ha. The largest deviations of yield indicators to control among varieties were: variety Podilska416 – 0.41 t/ha, variety Chernivetska9 – 0.27 t/ha and variety Agate – 0.66 t/ha, which exceeded the value of LSD$_{0.05}$ for the factor A (soybean variety) by 0.32, 0.18 and 0.57 t/ha, respectively.

Therefore, the variability of yield under the action of factor A is significant. But in some embodiments, such as 9, 10, 12, 15, 16, 17, 18, 22, 25, and 26, the difference in factor A is less than $LSD_{0.05}$ (-0.05; -0.07; 0.07; 0.03; -0.08; -0.08; -0.06; 0.06; -0.01; -0.06 and 0.09). Therefore, the influence of factor A on the background of options AB, AB2, AB1C, AB2C, A1, A1B, A1BC, A2, and A2B is not significant, but is within the error of the experiment. For factor C (sowing method) $LSD_{0.05}$ was also determined at the level of 0.09 t/ha and the largest deviations in the level of yield among sowing methods were in the wide-row method and were 1.61 and 0.27 t/ha, respectively, which exceeded the value of $LSD_{0.05}$ for factor B by + 1.52 t/ha and +0.18 t/ha.

Table 2. Significance of the influence of variety, norms of mineral fertilizers and sowing method on soybean yield in 2018.

A	C	B	Option number	Option code	$\bar{x}$	The difference in factors A	The difference in factors C	The difference in factors B	$LSD_{0.05}$	$s\bar{x}$ %
Podilska 1	15 cm	control	1	0	1.43	-	-	-		
		P60K30 + (N15)	2	B	1.59	-	-	0.16		
		N30P60K30 + (N15)	3	B1	2.03	-	-	0.6		
		N45P60K30 + (N15)	4	B2	2.19	-	-	0.76		
	45 cm	without fertilizers	5	C	2.41	-	0.98	-		
		P60K30 + (N15)	6	BC	2.63	-	1.04	0.22		
		N30P60K30 + (N15)	7	B1C	2.31	-	0.28	-0.1		
		N45P60K30 + (N15)	8	B2C	2.60	-	0.41	0.19		
Podilska 416	15 cm	without fertilizers	9	A	1.51	0.08	-	-		
		P60K30 + (N15)	10	AB	1.68	0.09	-	0.17		
		N30P60K30 + (N15)	11	AB1	2.22	0.19	-	0.71		
		N45P60K30 + (N15)	12	AB2	2.29	0.1	-	0.78		
	45 cm	without fertilizers	13	AC	2.58	0.17	1.07	-		
		P60K30 + (N15)	14	ABC	2.68	0.05	1.0	0.1		
		N30P60K30 + (N15)	15	AB1C	2.50	0.19	0.28	-0.08		
		N45P60K30 + (N15)	16	AB2C	2.75	0.15	0.46	0.17	0.26	4.30
Chernivetska 9	15 cm	without fertilizers	17	A1	1.43	0	-	-		
		P60K30 + (N15)	18	A1B	1.51	-0.08	-	0.08		
		N30P60K30 + (N15)	19	A1B1	1.95	-0.08	-	0.52		
		N45P60K30 + (N15)	20	A1B2	2.09	-0.1	-	0.66		
	45 cm	without fertilizers	21	A1C	2.38	-0.03	0.95	-		
		P60K30 + (N15)	22	A1BC	2.44	-0.19	0.93	0.06		
		N30P60K30 + (N15)	23	A1B1C	2.41	0.1	0.46	0.03		
		N45P60K30 + (N15)	24	A1B2C	2.49	-0.11	0.32	0.11		
Agate	15 cm	without fertilizers	25	A2	1.36	-0.07	-	-		
		P60K30 + (N15)	26	A2B	1.52	-0.07	-	0.16		
		N30P60K30 + (N15)	27	A2B1	1.59	-0.44	-	0.23		
		N45P60K30 + (N15)	28	A2B2	2.21	0,02	-	0,85		
	45 cm	without fertilizers	29	A2C	2.33	-0,08	0,97	-		
		P60K30 + (N15)	30	A2BC	2.68	0,05	1,16	0,35		
		N30P60K30 + (N15)	31	A2B1C	2.20	-0,11	0,61	-0,13		
		N45P60K30 + (N15)	32	A2B2C	2.54	-0,06	0,33	0,21		
$LSD_{0.05}$ for factors A, B, C			0.09	0.09	0.07					

Therefore, the increase in soybean yield due to the action of factor C (sowing method) is significant. It is also worth noting that in all cases, the difference in factor C is greater than LSD$_{0.05}$. Thus, the effect of any of the interactions on the background of factor C is not within the error.

Factor B (mineral fertilizer rate) also significantly affected soybean yields and this is indicated by the largest deviations among the mineral fertilizer rates N45P60K30 + (N15) and N30P60K30 + (N15), which were + 0.96 t/ha and – 0.25 t/ha, which is more than LSD$_{0.05}$ for factor B by +0.89 t/ha and -0.18 t/ha, but in options 24; 27; 31 the difference in factor B is less than LSD$_{0.05}$ (0.02, 0.01, 0.03, 0.07). Thus, the influence of factor B on the background of variants A1B2C, A2B1, A2B1C is not significant, but is within the error.

In addition, Fisher's actual criteria for factors A, B and C are 13.45, 237.07 and 43.76, respectively, which is more than the theoretical F0.95. Therefore, the null hypothesis H0: d = 0 – is rejected. Based on this, we can conclude that the influence of the variety, the rate of mineral fertilizers and the method of soybean sowing is reliable; Fisher's actual criteria for the interaction of factors AB and BC are 3.21 and 10.50, which is greater than Fteor., so the interaction of these factors should also be considered reliable. For the rest of the interactions of AC and ABC factors, Fisher's criteria are in the range of 0.28 and 0.88, which is much less than the theoretical indicators. Therefore, the interaction of combinations of these factors is unreliable. LSD$_{0.05}$ for the whole experiment was determined at the level of 0.27 t/ha. The value of the relative error (3.96%) indicates the high accuracy of the experiment.

In 2018, according to the analysis of variance of soybean yield data, it was found that LSD$_{0.05}$ for factor A (Table 2) was also 0.09 t/ha. The largest deviations of yield indicators to control among varieties were: variety Podilska416 – 0.19 t/ha, variety Chernivetska9 – 0.19 t/ha and variety Agate – 0.44 t/ha, which exceeded the value of LSD$_{0.05}$ for the factor and (soybean variety) by 0.10, 0.10 and 0.35 t/ha, respectively.

Therefore, the variability of yield under the action of factor A is significant. But in some embodiments, such as 9, 14, 17, 18, 19, 21, 25, 26, 28, 29, 30, and 32, the difference in factor A is less than LSD$_{0.05}$ (0.08; 0.05; 0; 0; -0.08; -0.08; -0.03; -0.07; -0.07; 0.02; -0.08; 0.05; -0.06 and 0.09). Therefore, the influence of factor A on the background of variants ABC, A1, A1B, A1B1, A1C, A2, A2B, A2B2, A2C, A2BC, A2B2C is not significant, but is within the error of the experiment.

For factor C (sowing method) LSD$_{0.05}$5 was also determined at the level of 0.09 t/ha and the largest deviations of the yield level among sowing methods were in the wide-row method and were respectively 1.16 and 0.28 t/ha, which exceeded the value of LSD 0,05 for factor B by + 1.07 t/ha and + 0.19 t/ha. Therefore, the increase in soybean yield due to the action of factor C (sowing method) is significant. It is also worth noting that in all cases, the difference in factor C is greater than LSD 0.05. Thus, the effect of any of the interactions on the background of factor C is not within the error.

Factor B (mineral fertilizer rate) also significantly affected soybean yields and this is indicated by the largest deviations among the mineral fertilizer rates N45P60K30 + (N15) and N30P60K30 + (N15), which were + 0.85 t/ha and - 0.13 t/ha, which is more than LSD 0.05 for factor B by +0.78 t/ha and -0.06 t/ha, but in options 22; 23 the difference in factor B is less than LSD 0.05 (+0.06; +0.03 <0.07). Thus, the influence of factor B on the background of variants A1BC, A1B1C is not significant, but is within the error.

In addition, Fisher's actual criteria for factors A, B and C are 9.06, 208.57 and 38.92, respectively, which is more than the theoretical values of F 0.95. Therefore, the null hypothesis H0: d = 0 - is rejected. Based on this, we can conclude that the influence of the variety, the rate of mineral fertilizers and the method of soybean sowing is reliable; Fisher's actual criteria for the interaction of AC factors are 3.37, which is greater than F teor., so the interaction of these factors should also be considered reliable. For the rest of the interactions of the factors AB, BC and ABC, Fisher's criteria are in the range of 0.58 - 0.74, which is much less than the theoretical indicators. Therefore, the interaction of combinations of these factors is unreliable.

LSD$_{0.05}$ for the whole experiment was determined at the level of 0.26 t/ha. The value of the relative error (4.30%) indicates the high accuracy of the experiment.

According to the analysis of variance of soybean yield data in 2019, it was found that LSD 0.05 for factor A (Table 3) was 0.10 t/ha. The largest deviations of yields to control among varieties were: cultivar Podilska416 – 0.37 t/ha, cultivar Chernivtsi9 – 0.32 t/ha and cultivar Agate -0.28 t/ha, which exceeded the value of LSD 0.05 for factor A (soybean cultivar) by 0,27, 0.22 and -0.18 t/ha, respectively. Therefore, the variability of yield under the action of factor A is significant. But in some embodiments, such as 13, 17, 18, 19, 20, 21, 24, 30, 31, 32, the difference in factor A is less than LSD 0.05 (0.08, 0.04, 0.05, 0.05, 0.04, 0.04, 0, 0.02, 0.06, 0.06 <0.10). Therefore, the influence of factor A on the background of variants AS, A1, A1B, A1B1, A1B2, A1C, A1B2C, A2BC, A2B1C, and A2B2C is not significant, but is within the error of the experiment.

For factor C (sowing method) HIP$_{0.05}$ was also determined at the level of 0.10 t/ha and the largest deviations of the yield level among sowing methods were in the wide-row method and were 1.21 and 0.2 t/ha, respectively, which exceeded the value of LSD$_{0.05}$ for factor B by + 1.11 t/ha and + 0.1 t/ha. Therefore, the increase in soybean yield due to the action of factor C (sowing method) is significant. It is also worth noting that in all cases, the difference in factor C is greater than LSD 0.05. Thus, the effect of any of the interactions on the background of factor C is not within the error.

Factor B (mineral fertilizer rate) also significantly affected soybean yields and this is indicated by the largest deviations among mineral fertilizer rates N45P60K30 + (N15) and N30P60K30 + (N15), which were 1.06 t/ha and 0.27 t/ha, which is more than HIP0.05 for factor B by 0.99 t/ha and 0.2 t/ha, but in options 8; 23 the difference in factor B is less than LSD$_{0.05}$ (0.03, 0.01 <0.07).

Thus, the influence of factor B on the background of variants B2C, A1B1C is not significant, but is within the error.

In addition, Fisher's actual criteria for factors A, B and C are 10.31, 200.70 and 28.39, respectively, which is more than the theoretical F0.95. Therefore, the null hypothesis H0: d = 0 - is rejected. Based on this, we can conclude that the influence of

the variety, the rate of mineral fertilizers and the method of soybean sowing is reliable; Fisher's actual criteria for the interaction of AC factors are 4.02, which is greater than F teor., so the interaction of these factors should also be considered reliable. For the rest of the interactions of factors AB, BC and ABC Fisher's criteria are in the range of 0.26-0.81, which is much less than the theoretical indicators. Therefore, the interaction of combinations of these factors is unreliable. LSD 0.05 for the whole experiment was determined at the level of 0.28 t/ha. The value of the relative error (3.83%) indicates the high accuracy of the experiment.

Given the obtained results of the reliability of the influence of experimental factors on LSD 0.05, we found that the largest number of unreliable differences was determined by factor A and their number fluctuated over the years of research within 10-12 variants of the experiment or it was 31.25-37.5% of the total number of options studied. Therefore, on the basis of the defined, it is possible to state that the investigated grades in the conditions of region provide rather close levels of productivity. In addition, we also found that over the years of research in options 17 (A1) and 18 (A1B) there was a constant unreliability of variability in yield levels.

Thus, this gives us reason to say that when growing soybeans in the region it is possible to successfully replace the variety Podilska 1 variety Chernivetska 9 and the most ambiguous will be the level of yield when growing varieties Podilska 416 and Agate.

When analyzing the reliability of factor B by LSD 0.05, it was found that the number of unreliable variants of the experiment was in the range of 2-3 or 6.25-9.38% of the total number of variants of the experiment. Thus, the influence of mineral fertilizer rates on soybean yield in the zone is much more significant compared to varieties. We also found that the 23 (A1B1C) variant, where the norm N30P60K30 + (N15) was applied, was most often unreliable. Therefore, in view of the above, we can say that the application of this rate of mineral fertilizers can provide a stable and stable increase in yield. With regard to factor C, the analysis of reliability for LSD 0.05 did not reveal any unreliable option and it should be noted that all differences were positive in favor of wide-row (45 cm) method of sowing. Thus, according to the results of the research, we received an unequivocal statement that in the conditions of the region the best way of sowing soybeans is wide-row with a row spacing of 45 cm.

Conclusion

The results of analysis of soybean yield in the experiment showed that varieties, rates of mineral fertilizers and sowing methods significantly affected the variability of the amount of grain, but in addition, we also determined the share of factors studied on soybean yield in the experiment to identify dependence of productivity formation and features of interrelations of factors and on this basis to optimize varietal agrotechnics of cultivation of this agricultural crop in the region. Thus, under the influence of hydrothermal conditions during the study period, the share of factors in the experiment changed. This was established by calculating the share of the factor in the total variance at a reliability level of P = 0.95 according to Fisher's test. Thus, the most significant effect on soybean yield in the conditions of the Right-Bank Forest-Steppe of Ukraine was the norm of mineral fertilizers and among its gradations the norm N30P60K30 + (N15) contributed to the best level of yield of this agricultural crop.

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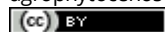
Appendix

Table 3. Significance of the influence of variety, norms of mineral fertilizers and sowing method on soybean yield in 2019.

A	C	B	Option number	Option code	$\bar{x}$	The difference in factors			$LSD_{0.05}$	$S\bar{x}$ %
						A	C	B		
Podilska 1	15 cm	without fertilizers (c)	1	0	1.77	-	-	-	028	3.83
		P60K30 + (N15)	2	B	1.86	-	-	0.09		
		N30P60K30 + (N15)	3	B1	2.43	-	-	0.66		
		N45P60K30 + (N15)	4	B2	2.51	-	-	0.74		
	45 cm	without fertilizers	5	C	2.90	-	1.13	-		
		P60K30 + (N15)	6	BC	3.05	-	1.19	0.15		
		N30P60K30 + (N15)	7	B1C	2.63	-	0.2	-0.27		
		N45P60K30 + (N15)	8	B2C	2.87	-	0.36	-0.03		
Podilska 416	15 cm	without fertilizers	9	A	1.98	0.21	-	-		
		P60K30 + (N15)	10	AB	2.23	0.37	-	0.25		
		N30P60K30 + (N15)	11	AB1	2.66	0.23	-	0.68		
		N45P60K30 + (N15)	12	AB2	2.67	0.16	-	0.69		
	45 cm	without fertilizers	13	AC	2.98	0.08	1.0	-		
		P60K30 + (N15)	14	ABC	3.19	0.14	0.96	0.21		
		N30P60K30 + (N15)	15	AB1C	2.89	0.26	0.23	-0.09		
		N45P60K30 + (N15)	16	AB2C	3.13	0.26	0.46	0.15		
Chernivetska 9	15 cm	without fertilizers	17	A1	1.73	-0.04	-	-		
		P60K30 + (N15)	18	A1B	1.91	0.05	-	0.18		
		N30P60K30 + (N15)	19	A1B1	2.38	-0.05	-	0.65		
		N45P60K30 + (N15)	20	A1B2	2.55	0.04	-	0.82		
	45 cm	without fertilizers	21	A1C	2.94	0.04	1.21	-		
		P60K30 + (N15)	22	A1BC	2.85	-0.2	0.94	-0.09		
		N30P60K30 + (N15)	23	A1B1C	2.95	0.32	0.57	0.01		
		N45P60K30 + (N15)	24	A1B2C	2.87	0	0.32	-0.07		
Agate	15 cm	without fertilizers	25	A2	1.61	-0.16	-	-		
		P60K30 + (N15)	26	A2B	1.96	0.1	-	0.35		
		N30P60K30 + (N15)	27	A2B1	2.15	-0.28	-	0.54		
		N45P60K30 + (N15)	28	A2B2	2.67	0.16	-	1.06		
	45 cm	without fertilizers	29	A2C	2.80	-0.1	1.19	-		
		P60K30 + (N15)	30	A2BC	3.07	0.02	1.11	0.27		
		N30P60K30 + (N15)	31	A2B1C	2.57	-0.06	0.42	-0.23		
		N45P60K30 + (N15)	32	A2B2C	2.93	0.06	0.26	0.13		
$LSD_{0.05}$ for factors A, B, C			0.10	0.10	0.07					