











Influence of agroecological methods on biometric indicators of corn

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ABSTRACT

All agricultural producers are fighting for high crop yields. To improve them, scientists and farms are constantly looking for optimal tillage, fertilizers, etc. Biofertilizers, containing so-called effective microorganisms, are more and more often used to ensure optimal plant nutrition. Many scientists have proven and described their positive effect subject to the use of a particular tillage and with which chemical fertilizers their effect is considered to be the best. To obtain high yields, it is also important to take into account the biometric indicators of plants. This article presents a study on determining the height and diameter of the corn stalk, as well as the height of attachment of the first completed cob. Therefore, in a three-factor experiment, we studied the effect of reversible (plowing to a depth of 25–28 cm) and irreversible types of tillage (subsurface cultivator to a depth of 25–28 cm and disking to a depth of 15–18 and 5–8 cm), as well as the effect of such soil probiotics as LEANUM and VITAMIN O7 (used before sowing and on the leaf) on medium-early and medium-ripened hybrids. It was found that all the studied biometric parameters of both hybrids in 2020–2022 were best affected by flat-cutting cultivation to a depth of 25–28 cm. Soil probiotics significantly affected plant height, mainly when applied by leaf. The height of attachment of the first cob for both hybrids was significantly affected by pre-sowing inoculation with both biofertilizers, as well as foliar dressing with LEANUM once and twice.

Keywords: climatic conditions, biofertilizer, organic farming, soil tillage, plants, yield.

INTRODUCTION

The use of foliar top dressing of agricultural crops has been practiced in the world and Ukraine for a long time. Mainly, mineral macro- and microfertilizers are used for this purpose, among them: “Ecolist Mono Zinc” [Palamarchuk & Solomon, 2021], “UAN” [Shinkaruk, 2021], “Micro-Mineralis Maize”, “Nutribor”, “Nutrimix” [Krestianinov et al., 2019] and many others. However, in recent years, biofertilizers that contain effective microorganisms have become increasingly popular. The influence of such fertilizers

on yield, plant habit and other indicators is described by many scientists [Datsko, 2021; Kevin et al., 2021; Piotrowska & Boruszko, 2022]. Studies on the effects of biological fertilizers used on the leaf and containing beneficial microorganisms in their composition have become increasingly common [Rybachok, 2019; Latkovic et al., 2020; Adajar & Taer, 2021; Tykhonova et al., 2021]. Nowadays, the trend of using biofertilizers as foliar top dressing can only grow, since the price of mineral fertilizers has increased significantly, and the effectiveness of fertilizers with beneficial microorganisms has been proven and is quite high

[Aquino et al., 2021; Saleem et al., 2021; Notunu et al., 2022; Hryhoriv et al., 2024].

However, not only biofertilizers, but also other factors such as weather conditions, tillage, varieties or hybrids, affect yields. The last of these factors plays an extremely important role. Thus, for corn plants, there are five groups of ripeness, divided according to the duration of the growing season, and, accordingly, the sum of active and effective temperatures. Thanks to this division, it is much easier to determine the necessary variety or hybrid of corn in certain climatic conditions.

The optimal combination of all factors leads the agricultural enterprise to obtain a good harvest. For example, scientists from Pakistan studied the effects of bacteria that stimulated plant growth under controlled conditions and investigated their effect on corn yield and drought resistance. The results showed that among all variants, the greatest effect was when bacterial preparations were applied to the leaf in the 3–4 leaf phase [Mubeen et al., 2021]. Similar results were obtained by Iranian scientists [Abadi et al., 2020]. However, when comparing the effectiveness of spraying corn with biologics on the leaf or applying it on the soil surface, spraying the leaf surface resulted in significantly lower yield results [Efthimiadou et al., 2020; Kolisnyk et al., 2024]. However, the data of scientists from Greece contradict this statement, since, according to their data, the method of using effective microorganisms does not affect the results of corn yield [Hryhoriv et al., 2021; Katsenios et al., 2022]. At the same time, Brazilian scientists who conducted studies with early-maturing corn hybrids found that spraying with a biological product containing *Azospirillum brasilense* did not affect the yield, but the diameter of the plant stem and the content of chlorophyll increased [Júnior et al., 2019; Karbivska et al., 2022a]. Whereas in another study, *A. brasilense* significantly affected the yield during seed inoculation, but in the plant spray variant did not affect this indicator [Muller et al., 2021; Karbivska et al., 2023].

It would be appropriate to add that the use of biofertilizers with microorganisms on the leaf contributes not only to improving yields, but also to protecting plants from pathogens (Khan, 2021). In particular, *Pseudomonas aeruginosa* of the MF-30 strain reduces the effects of plant disease and at the same time contributes to an increase in the mass of corn shoots and roots inoculated with *Rhizoctonia solani* during sowing [Singh et al., 2020].

Chinese scientists have also confirmed this hypothesis, in particular *Bacillus amyloliquefaciens* of the B9601-Y2 strain suppresses the development of Northern corn leaf spot [Cui et al., 2019].

Undoubtedly, highly productive plants have not only a higher yield, but also a more powerful stem. In addition, the height of cob attachment is also important. The lowest threshold for a combine harvester harvesting corn is 50 cm, the cobs below do not fall into the combine for threshing, but fall into the field, so any crop grown will be lost [Rudenko et al., 2021; Karbivska et al., 2022b].

Therefore, the aim of this study was to study the biometric characteristics of corn hybrids with FAO 280 and 380 under various types of soil tillage and treatment with probiotics.

MATERIAL AND METHODS

Experiments were conducted at the sites of Sumy National Agrarian University. Soil was chernozem typical low-humus medium loamy on the forest. The predecessor was winter wheat. The experiment was three-factor. Thus, Factor A – corn hybrids: medium-ripened Harmonium (FAO 380) and medium-early Hemingway (FAO 280). Factor B – treatment with soil probiotics, where control (K) was without any treatment, control and 1 treatment with LEANUM (L) on leaf (K+1L), control and 2 treatments with L on leaf (K+2L), inoculation of VITAMIN O7 before sowing (V), inoculation with V and 1 treatment with L on leaf (V+1L), inoculation with V and 2 treatments with L on leaf (V+2L), inoculation with L before sowing (L), inoculation with L and 1 treatment with L on leaf (L+1L), 1 inoculation and 2 1 treatments on leaf (L+2L). It is worth explaining that LEANUM is produced in liquid form, while VITAMIN O7 is produced in powder form. They contain effective microorganisms, vitamins, amino acids, enzymes, forms of macro- and microelements permitted for application by Organikstandart, etc.

Factor C – reversible tillage as a control (plowing to a depth of 25–28 cm) and irreversible: flat-cutting tillage to a depth of 25–28 cm, disking to a depth of 15–18 cm and disking to a depth of 5–8 cm. Weather conditions are shown in Figure 1. Biometric parameters are measured in the R2 phase on the BBCH scale. To perform the statistical analysis, Statistica 10.0 (StatSoft Inc., Tulsa, USA) software was used for MANOVA.

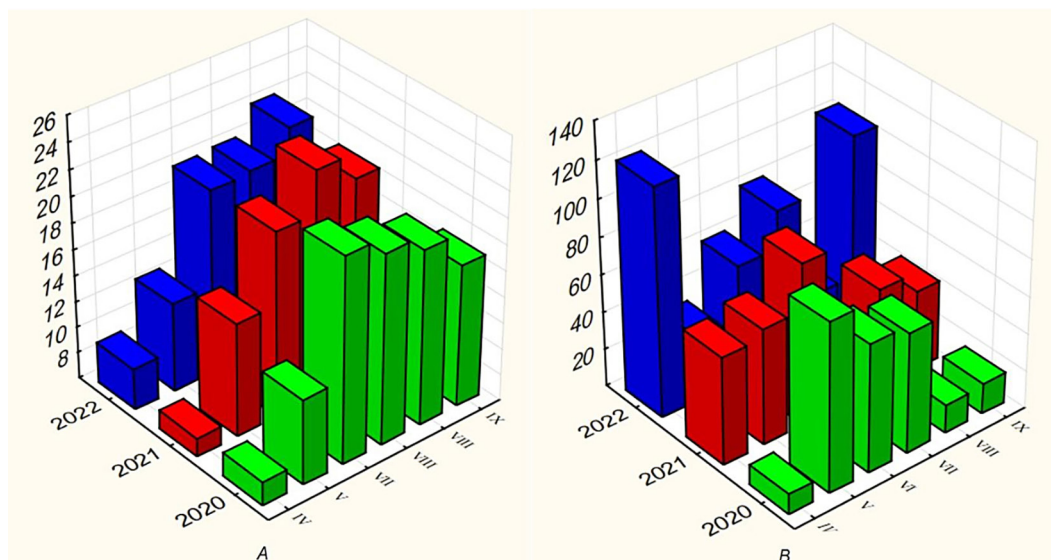


Figure 1. Climatic conditions in 2020–2022, where (A) is the temperature during the growing season (°C), (B) is precipitation (mm)

RESULTS AND DISCUSSION

Based on the results of multivariate dispersion analysis, it was found that the height of plants was significantly affected by both tillage and treatment with biologics, as well as the combination of these factors ($p < 0.05$) (Table 1). Thus, for the cultivation of Harmonium, IR 25–28 found the most significant impact on the height of corn plants. Among the treatments with biologics, all leaf spraying variants had a significant impact, but not for all types of tillage, only V+1, V+2 and L+1 contributed to a significant increase in the height

of plants. Significantly lower ($p < 0.05$) plants were on the IR 5–8 variants without any treatment with biofertilizers (C), as well as subject to inoculation of plants with V and R 25–28. For Hemingway, IR 25–28 and IR 15–18 had a significant effect compared to the control treatment. At the same time, among the treatments with biologics, the variants having a significant positive effect on any tillage were C+1, C+2, V+1, V+2, L+1 and L+2. It is worth noting that the options with seed inoculation does not work on any of the treatment variants except for IR 25–28 for growing Harmonium. In addition, Hemingway significantly (p

Table 1. Height of corn plants by variants in 2020–2022 ($\bar{x} \pm SD$), cm

Hybrid	Soil tillage	Biofertilizers								
		C	C+1	C+2	V	V+1	V+2	L	L+1	L+2
Harmonium	R 25-28	237.1±36. ^a	240.5±18.1 ^a	249.0±18.0 ^c	218.2±42.1 ^b	259.4±24.1 ^c	258.8±19.7 ^c	230.2±49.0 ^a	252.3±19.8 ^c	244.8±24.1 ^a
	IR 25-28	223.7±47.9 ^a	261.1±31.4 ^c	276.8±39.2 ^c	237.5±48.3 ^a	272.2±42.1 ^c	266.4±40.7 ^c	232.7±37.5 ^a	292.0±39.4 ^c	270.6±41.0 ^c
	IR15-18	236.5±41.7 ^a	247.3±19.6 ^a	252.3±15.6 ^c	238.3±36.8 ^a	259.8±20.5 ^c	268.8±21.5 ^c	225.0±43.5 ^a	251.3±27.9 ^c	247.2±24.5 ^a
	IR 5-8	220.4±54.6 ^b	244.0±15.4 ^a	241.9±16.1 ^a	236.7±35.7 ^a	255.7±22.3 ^c	251.4±20.5 ^c	226.1±41.5 ^a	258.0±25.8 ^c	243.4±26.2 ^a
Hemingway	R 25-28	239.4±43.2 ^a	253.0±36.3 ^c	254.8±24.7 ^c	234.9±46.3 ^a	256.0±29.3 ^c	265.7±23.4 ^c	232.9±43.7 ^a	256.2±28.7 ^c	256.0±23.1 ^c
	IR 25-28	251.5±43.1 ^c	276.4±28.0 ^c	275.4±36.0 ^c	239.7±51.4 ^a	284.2±36.9 ^c	277.7±34.0 ^c	233.4±48.3 ^a	279.9±39.0 ^c	281.6±37.2 ^c
	IR15-18	256.2±37.5 ^c	267.2±23.3 ^c	269.7±32.3 ^c	242.2±48.6 ^a	260.8±24.6 ^c	266.2±23.0 ^c	229.8±49.4 ^a	255.4±28.2 ^c	272.5±28.7 ^c
	IR 5-8	248.3±36.5 ^a	256.7±30.8 ^c	254.1±22.6 ^c	246.0±44.0 ^a	263.9±23.2 ^c	255.7±24.3 ^c	230.2±46.8 ^a	255.6±26.6 ^c	264.0±29.9 ^c

Note: \bar{x} – average value; SD – standard deviation; abc – LSD_{05} of the studied variants according to the Fischer criterion.

<0.05) surpasses Harmonium in height by 4.3%. The level of confidence factor in the study of the height of attachment of the cob on the corn stalk according to the results of MANOVA was also high ($p < 0.05$) (Table 2). For the cultivation of Harmonium, the lowest rate compared to the control was on the IR 5–8 and C+2 variants. At the same time, the attachment of the cob higher than the control was observed for IR 25–28 tillage and any treatment with biofertilizers. It is worth noting that on all variants with inoculation during sowing and treatment with biofertilizer on the leaf, the cobs were located higher on the stem than the control variant. During the cultivation of Hemingway, the cobs subject to IR 5–8 tillage and C+1 and C+2 leaf treatment variants were attached at the lowest height. The treatment with IR 25–28 again marked the highest indicators as well as the treatment with biofertilizers, except for L+1. In addition, for the cultivation of Hemingway, on average, the attachment of the cob is noted at a height of 83.2 cm, while Harmonium – at a height of 68.4 cm. That is, the height of attachment of the cobs during the cultivation of Harmonium is significantly lower than that of another hybrid ($p < 0.05$).

The diameter of the corn stem during cultivation of both hybrids was significantly larger ($p < 0.05$) when using IR 25–28 tillage (Table 3). For Harmonium, a significant effect on the diameter of the stem for all tillage was subject to the treatment with L and L+2. For Hemingway, it is not possible to single out one treatment with

biologics, which will increase the diameter of the stem for any treatment, but it is worth noting that when using treatments with IR 5-8 and C+1, V+2 and L+2, the diameter is significantly smaller ($p < 0.05$) than the control. It is worth noting that the average stem diameter of both hybrids almost does not differ from each other, for example, for Harmonium it is 1.86 cm, and for Hemingway – 1.88, but according to ANOVA, the difference between them is still significant at $p < 0.05$.

Taking into consideration the results obtained, we can conclude that the biometric indicators of corn plants primarily depend on the hybrid. According to all the indicators analyzed, Harmonium is dominated by Hemingway. Some researchers who have studied a similar issue have slightly different conclusions. Thus, for example, the height of an early-maturing and medium-early hybrid, when growing on typical low-humus chernozem, was best affected by plow tillage (plowing to a depth of 20–22 cm), while the medium-maturing hybrid was positively affected by shallow tillage to a depth of 8-10 cm [Len et al., 2021; Masliiov et al., 2020]. When growing other hybrids on the same soil, it was found that plowing to a depth of 20-22 cm again had a positive effect on the height of plants, and the medium-early hybrid was most affected [Totskiy & Len, 2020]. Other studies have also confirmed that plowing to a depth of 20–22 cm has a positive effect on the height of medium-early corn hybrids [Mizai et al., 2018]. At the same time, for growing corn in the conditions of Sumy NAU,

Table 2. Height of attachment of the first corn cob according to the variants in 2020–2022 ($\bar{x} \pm SD$), cm

Hybrid	Soil tillage	Biofertilizers								
		C	C+1	C+2	V	V+1	V+2	L	L+1	L+2
Harmonium	R 25-28	52.2± 9.2a	52.0± 6.2a	52.8± 7.4a	68.8± 9.3c	72.7± 9.0c	71.9± 9.9c	83.7± 7.9c	82.0± 6.5c	86.1± 6.6c
	IR 25-28	58.6± 8.9c	62.5± 7.5c	63.4± 6.4c	73.2± 8.9c	73.1± 7.1c	73.8± 7.2c	87.4± 7.7c	88.2± 5.9c	86.5± 11.3c
	IR15-18	60.5± 9.1c	59.4± 7.0c	53.3± 6.9a	70.2± 10.2c	66.7± 7.0c	66.9± 7.7c	76.2± 9.4c	75.6± 6.1c	75.4± 7.0c
	IR 5-8	53.9± 8.2a	51.3± 6.6a	49.7± 6.4b	70.0± 10.9c	65.2± 9.9c	65.0± 10.1c	72.6± 11.5c	72.8± 9.6c	68.4± 8.2c
Hemingway	R 25-28	74.8± 10.8a	77.4± 6.3c	76.1± 6.8a	91.2± 9.0c	88.6± 7.8c	91.1± 7.3c	87.8± 8.9c	86.3± 8.3c	83.1± 6.7c
	IR 25-28	85.9± 10.2c	87.6± 6.5c	88.7± 6.3c	91.1± 12.7c	97.6± 6.6c	97.7± 8.3c	90.5± 8.3c	95.6± 5.8c	91.5± 6.3c
	IR15-18	72.7± 10.8a	73.5± 7.6a	75.0± 8.2c	88.3± 8.6c	87.9± 8.4c	86.3± 7.6c	83.3± 11.4c	80.4± 8.0c	81.7± 7.6c
	IR 5-8	67.8± 9.5b	68.2± 8.7b	70.7± 8.6b	86.6± 12.8c	77.5± 6.7c	80.0± 12.1c	79.0± 10.2c	76.8± 8.9a	77.6± 8.6c

Note: \bar{x} – average value; SD – standard deviation; abc – LSD_{05} of the studied variants according to the Fischer criterion

Table 3. Corn stalk diameter in 2020–2022 ($\bar{x}\pm SD$), cm

Hybrid	Soil tillage	Biofertilizers								
		C	C+1	C+2	V	V+1	V+2	L	L+1	L+2
Harmonium	R 25-28	1.7± 0.2a	1.7± 0.2a	1.8± 0.2c	1.7± 0.2a	1.7± 0.1a	1.8± 0.1c	1.8± 0.2c	1.8± 0.2c	1.9± 0.2c
	IR 25-28	1.8± 0.2c	2.0± 0.1c	2.2± 0.2c	2.2± 0.1c	2.0± 0.2c	2.1± 0.1c	1.9± 0.2c	1.9± 0.2c	2.0± 0.3c
	IR15-18	1.7± 0.3a	1.8± 0.1c	1.7± 0.1a	1.8± 0.2c	1.9± 0.2c	1.7± 0.1a	1.8± 0.2c	1.7± 0.2a	1.8± 0.2c
	IR 5-8	1.6± 0.2a	1.7± 0.2a	1.6± 0.1a	1.6± 0.1a	1.8± 0.2c	1.7± 0.1a	1.8± 0.2c	1.7± 0.2a	1.8± 0.2c
Hemingway	R 25-28	1.7± 0.1a	1.8± 0.1a	1.8± 0.2a	1.8± 0.2a	1.8± 0.2a	1.9± 0.2c	1.8± 0.2a	1.8± 0.1a	1.9± 0.2c
	IR 25-28	2.1± 0.2c	2.0± 0.1c	2.1± 0.2c	2.1± 0.2c	2.2± 0.2c	2.0± 0.2c	2.0± 0.2c	2.1± 0.1c	2.3± 0.1c
	IR15-18	1.7± 0.2a	1.7± 0.2a	1.7± 0.2a	1.8± 0.2a	1.8± 0.1a	1.8± 0.2a	1.9± 0.2c	1.7± 0.2a	1.7± 0.2a
	IR 5-8	1.7± 0.2a	1.6± 0.1b	1.7± 0.2a	1.7± 0.2a	1.7± 0.2a	1.6± 0.2b	1.8± 0.3a	1.7± 0.1a	1.6± 0.1b

Note: \bar{x} – average value; SD – standard deviation; abc – LSD_{05} of the studied variants according to the Fischer criterion.

the best result was shown by the medium-ripened hybrid Forteza, compared to the medium-late DM Native and medium-ripened DM Skarb [Radchenko et al., 2022]. When studying the effect of inoculant and foliar top dressing on the height of corn when growing on gray forest soils, it was found that inoculation still affected the height of the mid-early hybrid [Mazur et al., 2018]. With the use of Groundfix biofertilizer at a rate of 8 l ha⁻¹, the height of the medium-early corn hybrid significantly increased compared to the control and lower standards for the use of biological products in the conditions of Vinnytsia region. The studies comparing the effects of inoculation and chemical fertilizers on typical chernozem, where the main tillage was plowing to a depth of 23–25 cm showed that the height of the ultra-early hybrid was best affected by biologics compared to the control and chemical fertilizers, but in other cases the biologics exceeded the control for the variety and medium-early hybrid, but not chemical fertilizers [Telychko, 2020].

The height of attachment of the first formed cob during the cultivation of medium-early Hemingway is 17.7% higher than medium-ripened Harmonium, if we take into account all cultivation variants. This issue has been investigated by many scientists, since this characteristic significantly affects the final yield of the crop. Thus, Rudavska & Hlyva [2018] studied the height of attachment of the cobs of early-maturing and medium-early hybrids on dark gray podzolic gleyic soils with different fertilizers and identified clear

boundaries for each hybrid. Zakharchenko [2019] described the height of attachment of the cob subject to flat-cutting tillage to a depth of 25–27 when growing a medium-early corn hybrid. It is worth noting that the use of microfertilizers increases the height of plants, the height of attachment of the cob and the diameter of the stem. An increase in the stem diameter when using an inoculant containing *Azospirillum brasilense* and *Bacillus subtilis* has been proven by scientists from Brazil [Galindo et al., 2019; Moreno et al., 2021].

CONCLUSIONS

It was found that all the studied biometric parameters of both hybrids in 2020–2022 were best affected by flat-cutting cultivation to a depth of 25–28 cm. Soil probiotics significantly affected plant height, mainly when applied by leaf. The height of attachment of the first cob for both hybrids was significantly affected by pre-sowing inoculation with both biofertilizers, as well as foliar dressing with LEANUM once and twice. The stem diameter with growing Harmonium was high subject to inoculating with LEANUM and its double foliar application for any types of tillage. For Hemingway, it is impossible to distinguish such an effect, however, it is worth noting that when using disking to a depth of 5–8 cm and some treatments with a soil probiotic, the corn stem diameter indicators were significantly lower compared to the control. It is worth adding that

the mid-early Hemingway was dominated by the mid-ripened Harmonium in height, diameter and height of the corn cob attachment on all variants with an indicator of 4.3%.

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