ISSN 2226-3063 e-ISSN 2227-9555
Modern Phytomorphology 13: 1–4, 2019

RESEARCH ARTICLE

Leaf area index of sweet corn (*Zea mays ssp. saccharata* L.) crops depending on cultivation technology in the drip-irrigated conditions of the south of Ukraine

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Received: 26. 11. 2018 | **Accepted:** 01. 01. 2019 | **Published:** 5. 01. 2019

Abstract

The paper presents the results of the study dedicated to the investigation of sweet corn leaf apparatus growth and development in dependence to the crop cultivation technology elements, viz. depth of plowing, mineral fertilizers application doses, plants density, in the drip-irrigated conditions of the South of Ukraine. The field trials were carried out during three years (2014-2016) by using the split-plot design method in four replications with accordance to the modern requirements of the experimental work in agronomy. The results of the study showed the significant effect of all the studied agro technological treatments on the crop leaf apparatus. The highest Leaf Area Index (LAI) that averaged to 3.72 was obtained under moldboard plowing at the depth of 20-22 cm, fertilization with $N_{120}P_{120}$, and plants density of 80000 ha^{-1}. The total amplitude of fluctuation of LAI averaged to 2.42. Increased plowing depth improved LAI of sweet corn only under the non-fertilized conditions, however, increased fertilizers doses and thickening of the crops positively affected the studied bio-metric index.

Keywords: Depth of plowing, Leaf area index, Mineral fertilizers, Plants density, Sweet corn

Introduction

The Leaf Area Index (LAI) is one of the most widely used bio-metric parameters of crops for estimation of their potential photosynthetic activity efficiency, biomass, and net dry matter productivity prediction (Williams et al. 1965). It is considered that LAI values are in strong linear correlation with crops yields (Ashley et al. 1965; Eik & Hanway 1966). It is also used in different artificial mathematical crop simulation models, which are aimed to help proper agronomic management of the concrete crop (Moulin et al. 1998; Doraiswamy et al. 2004; Wu et al. 2007). LAI is the index that shows the current state of development of crops for the concrete period of vegetation pointing out present problems and weak points in the crop management.

Every crop has its own optimal LAI values. Either too low or too high LAI is an indicator of some unfavorable conditions that has been formed in the field. It is used as a crop growth indicator (Kross et al. 2015; Campos-Taberner et al. 2016). For example, LAI could be used for estimation of the cultivation technology treatments efficiency in satisfying crops biological requirements. The goal of our study is the assessment of various sweet corn cultivation technology elements efficiency in providing the crop with favorable conditions for its growth and development by using the LAI values measured at the key stages of the crop vegetation.

Materials and Method

The field trials with sweet corn crops were carried out during the period of 2014-2016 by using the split plot design method in four replications at the drip-irrigated lands of the agricultural cooperative farm "Radianska Zemlia" of Kherson region, Ukraine (experimental field coordinates are: latitude 46°43 42′′N, longitude 32°17′38′′E, altitude 42 m). The trials were dedicated to the study of such cultivation technology elements as: Factor A-depth of moldboard plowing (20-22, 28-30 cm); Factor B-mineral fertilizers application doses (N_0P_0; $N_{60}P_{60}$; $N_{120}P_{120}$); Factor C-plants density (35000, 50000, 65000, 80000 plants ha^{-1}). We used the sweet corn cultivar Brusnytsia (standard sweet-*su*). The previous crop was winter wheat. After the harvesting of the previous crop we conducted harrowing at the depth of 10-12 cm, and then we performed moldboard plowing with accordance to the study design. Mineral fertilizers (ammonium nitrate and superphosphate) were applied with accordance to the study design at the pre-plowing period.

Soil cultivations at the depth of 8-10, and 5-6 cm were conducted in the spring before sowing. Sweet corn was sown at the depth of 5-6 cm with the inter-row spacing of 70 cm. The time of sowing varied from year to year and was: 1st of May in 2014, 22nd of May in 2015 and 21st of May in 2016, respectively. Herbicide Harnes (*Acetochlor*, 900 g L^{-1} of the active substance) was applied before sowing of the crop in the dose of 2.0 L ha^{-1}. Karate Zeon insecticide (*Lambda-cyhalothrin*, 50 g L^{-1} of the active substance) was applied at the stage of 3-5 leaves of the crop in the dose of 0.2 L ha^{-1}. Master Power herbicide (*Foramsulfuron*, 31.5 g L^{-1}, *Iodosulfuron*, 1.0 g L^{-1}, *Tienecarbazon-methyl*, 10 g L^{-1}, *Cyprosulfamide* (antidote), 15 g L^{-1} of the active substances) was applied at the stage of 7-8 leaves of the crop in the dose of 1.25 L ha^{-1}. Koragen insecticide (*Chlorantraniliprole*, 200 g L^{-1} of the active substance) was used at the beginning of the panicle earing period in the dose of 0.1 L ha^{-1} dose. Soil moisture during the crop vegetation was kept up at the level of 80% of the field water holding capacity by the means of drip irrigation.

We used the water from the Ingulets irrigation system, which belongs to the second class water with accordance to the national and FAO standards, and its suitability for irrigation is limited because of salinization and alkalization hazards (Lykhovyd & Kozlenko 2018). Irrigation water was applied to the field in such amounts: in 2014-10 times by 5 mm until the 7-8 leaves stage of the crop and 12 times by 10 mm during the rest of the vegetation period; in 2015-6 times by 5 mm until the 7-8 leaves stage of the crop and 9 times by 10 mm during the rest of the vegetation period; in 2016-8 times by 5 mm until the 7-8 leaves stage of the crop and 12 times by 10 mm during the rest of the period. LAI (m^2/m^2) represents the amount of leaf material in an ecosystem and is geometrically defined as the total one-sided area of photosynthetic tissue per unit ground surface area (Gobron 2008). The leaf area per plant (LAP) was directly measured at the stage of milk ripeness of the crop grain. We took into account only green leaves, no dead leaves were measured.

The measurements were conducted in four replications on the previously marked plants within the experimental plots (Ushkarenko et al. 2014). The leaf area was recalculated to m2/plant. Statistical evaluation of the obtained results was performed by using the multiple analyses of variance (ANOVA) within Agrostat add-on of Microsoft Office Excel software (Rosner 2006). The least significant difference (LSD) was estimated for the reliability level of 95%.

Results

The maximum pure productivity of the crops might be achieved at the LAI values of 4.0-5.0. The highest LAI value in our study was 3.72, and it was determined on sweet corn crops cultivated with moldboard plowing at the depth of 20-22 cm, mineral fertilizers application dose of $N_{120}P_{120}$, and plants density of 80000 ha^{-1} (Tab. 1).

LAI increases with less plowing depth (by 9.97%), better nutrition (by 7.37% and 24.65% with every increase in fertilizers dose, or by 33.84% in general), and crops thickening (by 34.25%, 25.51%, 16.07% with every increase in plants density, or by 95.58% in general). We should admit that deep moldboard plowing had positive effect on the parameter under the non-fertilized conditions. The total amplitude of LAI fluctuation in the study was 2.42. The results of ANOVA proved significance of the differences between the investigated treatments at the reliability level of 95%. So, all the studied elements of cultivation technology are effective instruments for sweet corn growth and productivity management.

However, we did not achieve the highest LAI values at any of the studied treatments. Therefore, we conclude that further investigations with more complex design have to be conducted for creation of the agro technology, which will be able to provide LAI values close to 4.0.

Discussion

Cultivation technology considerably affects LAI of crops. It was shown by the results of our study, and previously conducted researches that LAI strongly depends on fertilization (Vose & Allen 1988). The results of a study on winter wheat growth peculiarities under various fertilization proved significant decrease in LAI of the crops, which suffered from nutritive stress (Hinzman et al. 1986). On the other hand, investigations showed

Table 1. Average leaf area per plant (LAP) and leaf area index (LAI) of sweet corn crops depending on depth of plowing, mineral fertilizers application doses, and plants density. Mean value ± SD.

Depth of plowing (Factor A)	Mineral fertilizers dose (Factor B)	Plants density (Factor C)							
		35000 ha^{-1}		50000 ha^{-1}		65000 ha^{-1}		80000 ha^{-1}	
		LAP	LAI	LAP	LAI	LAP	LAI	LAP	LAI
20-22 cm	N_0P_0	0.37 ± 0.020	1.30 ± 0.07	0.35 ± 0.014	1.77 ± 0.07	0.34 ± 0.013	2.22 ± 0.09	0.33 ± 0.015	2.60 ± 0.12
	$N_{60}P_{60}$	0.43 ± 0.035	1.51 ± 0.12	0.39 ± 0.041	1.97 ± 0.21	0.38 ± 0.041	2.49 ± 0.24	0.36 ± 0.036	2.86 ± 0.29
	$N_{120}P_{120}$	0.57 ± 0.078	1.99 ± 0.28	0.53 ± 0.085	2.66 ± 0.42	0.50 ± 0.086	3.27 ± 0.56	0.46 ± 0.093	3.72 ± 0.75
28-30 cm	N_0P_0	0.38 ± 0.021	1.31 ± 0.08	0.36 ± 0.016	1.79 ± 0.08	0.35 ± 0.015	2.25 ± 0.10	0.33 ± 0.015	2.63 ± 0.12
	$N_{60}P_{60}$	0.39 ± 0.026	1.35 ± 0.09	0.37 ± 0.018	1.84 ± 0.09	0.36 ± 0.016	2.33 ± 0.11	0.34 ± 0.013	2.69 ± 0.11
	$N_{120}P_{120}$	0.46± 0.032	1.59 ± 0.11	0.42 ± 0.029	2.12 ± 0.15	0.41 ± 0.032	2.69 ± 0.21	0.40 ± 0.029	3.20 ± 0.23

Note: LSD_{05} for the studied factors and their interaction for LAP (m^2): A-0.002; B-0.001; C-0.002; ABC-0.005. LSD_{05} for the studied factors and their interaction for LAI (m^2/m^2): A-0.011; B-0.007; C-0.009; ABC-0.024. Differences between all the studied variants are significant at the reliability level of 95%

significant increase in LAI due to better nutrition of the studied crops (Heilman & Fu-Guang 1994; Verma & Acharya 1996; Peltonen-Sainio et al. 1997).

Tillage is also considered as an effective agronomic measure for crop growth management. The results of our study showed significant increase in LAI with plowing at the less depth. Another study conducted with cocoyam crop proved considerable difference in LAI measured on the tilled and no-tilled treatments (Anikwe et al. 2007). Similar results were obtained for soybean, where conventional tillage system showed much better results in LAI than no-till (Yusuf et al. 1999). Minimum tillage slowed down development of corn crops in comparison to conventional tillage (Raimbault & Vyn 1991).

Investigations on LAI showed that this bio-metric parameter is highly dependent on plants density at the late stages of corn growth and development (Bavec & Bavec 2002). Our study proved the above-mentioned statement, and the results showed significant increase of LAI with increased plants density of sweet corn crops (coefficient of correlation was 0.85). This is because of better coverage of the crop leaf apparatus of soil surface with more plants per unit of the area. It was also stated that more uniform crops with an optimal plant density provide better LAI, and, as a result, crop productivity (Olsen & Weiner 2007).

So, LAI is greatly affected by the studied cultivation technology treatments, and further investigations in the field should provide us with more scientific data for development of the most optimal agro technology that will be able to grant the highest crop productivity in the concrete environmental conditions.

Conclusion

The maximum LAI of sweet corn crops, which averaged to 3.72, was determined under the cultivation technology treatments with moldboard plowing at the depth of 20-22 cm, application of mineral fertilizers in dose of N120 P120, and plants density of 80000 ha^{-1}. A tendency to significant decrease of LAI was observed under the conditions of increased plowing depth, worse nutrition of the crop, and crop thinning.

References

Williams W.A., Loomis R.S., Lepley C.R. 1965. Vegetative growth of corn as affected by population density. II. Components of growth, net assimilation rate and leaf-area index. *Crop Sci.* **5:** 215-219.

Ashley D.A., Doss B.D., Bennett O.L. 1965. Relation of cotton leaf area index to plant growth and fruiting. *Agron. J.* **57:** 61-64. https://doi.org/10.2134/agronj1965.00021962005700010020x

Eik K., Hanway J.J. 1966. Leaf area in relation to yield of corn grain. *Agron. J.* **58:** 16-18. https://doi.org/10.2134/agronj1966.00021962005800010006x

Moulin S., Bondeau A., Delecolle R. 1998. Combining agricultural crop models and satellite observations: from field to regional scales. *Int. J. Remote Sens.* **19:** 1021-1036. https://doi.org/10.1080/014311698215586

Doraiswamy P.C., Hatfield J.L., Jackson T.J., Akhmedova B., Prueger J., Stern A. 2004. Crop condition and yield simulations using Landsat and MODIS. *Remote Sens. Environ.* **92:** 548-559. https://doi.org/10.1016/j.rse.2004.05.017

Wu J., Wang D., Bauer M.E. 2007. Assessing broadband vegetation indices and QuickBird data in estimating leaf area index of corn and potato canopies. *Field Crops Res.* **102:** 33-42. https://doi.org/10.1016/j.fcr.2007.01.003

Kross A., Lapen D.R., McNairn H., Sunohara M., Champagne C., Wilkes G. 2015. Satellite and in situ derived corn and soybean biomass and leaf area index: Response to controlled tile drainage under varying weather conditions. *Agric. Water Manag.* **160:** 118-131. https://doi.org/10.1016/j.agwat.2015.06.007

Campos-Taberner M., García-Haro F.J., Camps-Valls G., Grau-Muedra G., Nutini F., Crema A., Boschetti M. 2016. Multitemporal and multiresolution leaf area index retrieval for operational local rice crop monitoring. *Remote Sens. Environ.* **187:** 102-118. https://doi.org/10.1016/j.rse.2016.10.009

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

Gobron N. 2008. Leaf Area Index (LAI). terrestrial essential climate variables for climate change assessment, mitigation and adaptation. *GTOS*: 52.

Ushkarenko V.O., Kokovikhin S.V., Holoborodko S.P., Vozhehova R.A. 2014. Methodology of the field experiment (irrigated agriculture).

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

Vose J.M., Allen H.L. 1988. Leaf area, stemwood growth, and nutrition relationships in loblolly pine. *Forest Sci.* **34:** 547-563. https://doi.org/10.1093/forestscience/34.3.547

Hinzman L.D., Bauer M.E., Daughtry C.S.T. 1986. Effects of nitrogen fertilization on growth and reflectance characteristics of winter wheat. *Remote Sens. Environ.* **19:** 47-61. https://doi.org/10.1016/0034-4257(86)90040-4

Heilman P.E., Fu-Guang X. 1994. Effects of nitrogen fertilization on leaf area, light interception, and productivity of short-rotation Populus trichocarpa × Populus deltoides hybrids. *Can. J. Forest Res.* **24:** 166-173. https://doi.org/10.1139/x94-022

Verma M.L., Acharya C.L. 1996. Root development, leaf area index, water use and yield of rainfed wheat under different soil water conservation practices and levels of nitrogen. *J. Indian Soc. Soil Sci.* **44:** 625-632. http://www.indianjournals.com/ijor.aspx?target=ijor:jisss&volume=44&issue=4&article=010

Peltonen-Sainio P., Forsman K., Poutala T. 1997. Crop management effects on pre- and post-anthesis changes in leaf area index and leaf area duration and their contribution to grain yield and yield components in spring cereals. *J. Agron. & Crop Sci*. **179:** 47-61. https://doi.org/10.1111/j.1439-037X.1997.tb01146.x

Anikwe M.A.N., Mbah C.N., Ezeaku P.I., Onyia V.N. 2007. Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (Colocasia esculenta) on an ultisol in southeastern Nigeria. *Soil & Til. Res.* **93:** 264-272. https://doi.org/10.1016/j.still.2006.04.007

Yusuf R.I., Siemens J.C., Bullock D.G. 1999. Growth analysis of soybean under no-tillage and conventional tillage systems. *Agron. J.* **91:** 928-933. https://doi.org/10.2134/agronj1999.916928x

Raimbault B.A., Vyn T.J. 1991. Crop rotation and tillage effects on corn growth and soil structural stability. *Agron. J.* **83:** 979-985. https://doi.org/10.2134/agronj1991.00021962008300060011x

Bavec F., Bavec, M. 2002. Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400). *Eur. J. Agron.* **16:** 151-159. https://doi.org/10.1016/S1161-0301(01)00126-5

Olsen J., Weiner J. 2007. The influence of Triticum aestivum density, sowing pattern and nitrogen fertilization on leaf area index and its spatial variation. *Basic Appl. Ecol*. **8:** 252-257. https://doi.org/10.1016/j.baae.2006.03.013