

SOYBEAN YIELD ESTIMATION MODELS BASED ON BIOMETRIC PARAMETERS

JURJESCU ANDREEA LIDIA¹, KINCEL KLAUDIA^{1,2},
HORABLAGA MARINEL NICOLAE^{1,2}, SALA FLORIN^{*1,2}

¹Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania

²University of Life Sciences "King Mihai I" from Timisoara, Timișoara, 300645, Romania

*Corresponding author's e-mail: florin_sala@usvt.ro

Abstract: The study analyzed the yield of the soybean crop to describe the yield variation in relation to biometric parameters. The Iris soybean variety was cultivated within ARDS Lovrin, in a non-irrigated system. The biometric parameters of soybean pods (PL - pod length, cm; Pwdt - pod width, cm; PsW - pod shells weight, g; GW - grain weight, g; PW - pod weight, g) and yield (Y, kg ha⁻¹) were determined. The series of values of the biometric parameters showed a normal distribution, with $r > 0.900$. The regression analysis led to models in the form of equations and graphic models (3D, isoquants), which described with statistical certainty the yield variation in relation to the considered biometric parameters. The calculated RMSEP parameter confirmed that yield estimation based on PL and Pwdt parameters was possible under high safety conditions in the study conditions (RMSEP = 492.113 kg ha⁻¹). In the case of the other biometric parameters, the prediction reliability was confirmed at the level of RMSEP = 568.445 kg ha⁻¹ (PW, and GW), respectively RMSEP = 568.022 kg ha⁻¹ (PW, and PsW).

Key words: models, productivity elements, regression analysis, soybean, yield.

INTRODUCTION

Soybean is one of the main agricultural crops on a global scale [7]. Within agricultural crops, soybean is a plant of high importance for the production of proteins and oil, the content of nutritional principles, but also for the agronomic advantages it presents through nitrogen fixation and ecosystem benefits [3,13]. As a result of the importance of soybean production, there are studies and concerns for the expansion of soybean crop in new areas [7].

Soybean yield is the result of the interaction between cultivated genotypes, agricultural technologies and environmental factors. New breeding methods and technologies, based on biotechnology, are of interest for obtaining more productive genotypes and improving soybean yields [5,16].

In some areas of the world, the conventional soybean cultivation systems make the yields low, the ecosystem benefits low, and the farmers' interest in this crop low [14]. The authors have identified different categories of factors, of a technological, ecological and social nature, which influence the yields of the soybean crop in the study area.

The production differences in the soybean crop, between different categories of farmers, were explained based on the differences in technology, the allocation of inputs, especially fertilizers, the quality of the biological material and the level of training of the farmers [12].

The variation in soybean production was associated with the stress generated by environmental factors, limitations of genotypes, inadequate elements of technology, as well as economic policies [10]. The quality of biological material is an important component for increasing soybean yields [9].

Morphological characters and productivity elements of soybean plants were studied in relation to environmental factors, with stress factors, for the formation and optimization of yields [8].

The present study analyzed the soybean yield under non-irrigated crop conditions, in relation to certain productivity parameters, and found yield variation models, in the form

of equations and graphic models.

MATERIALS AND METHODS

The study was carried out in the climate and soil conditions specific to ARDS Lovrin, in the 2023-2024 agricultural year. The Iris soybean variety was cultivated in a non-irrigated system. An appropriate technology for soybeans, specific to the study area, was applied. The sowing was done in the middle of April, 2024. The maintenance works ensured adequate conditions for plant growth, associated with the climatic conditions specific to the agricultural year.

In relation to the purpose of the study, the values of some productivity parameters were determined, such as pod dimensions (length - PL, width - Pwdt), pod and grain weight (PW, PsW, GW). The determinations were made on plant samples harvested at the physiological maturity of the plants [11].

The experimental data were analyzed mathematically and statistically appropriately, in order to estimate soybean production based on the determined biometric parameters. The statistical calculation module in EXCEL was used, presumably dedicated applications [6,17].

RESEARCH RESULTS

The values of the productivity parameters analyzed for the soybean crop showed a normal distribution, under conditions of $r = 0.979$ (PL parameter), $r = 0.937$ (Pwdt parameter), $r = 0.985$ (PsW parameter), $r = 0.979$ (GW parameter), $r = 0.974$ (PW parameter), $r = 0.964$ (Y parameter). The representation of the distribution of data series, as normal probability plot is presented for productivity parameters in figure 1.

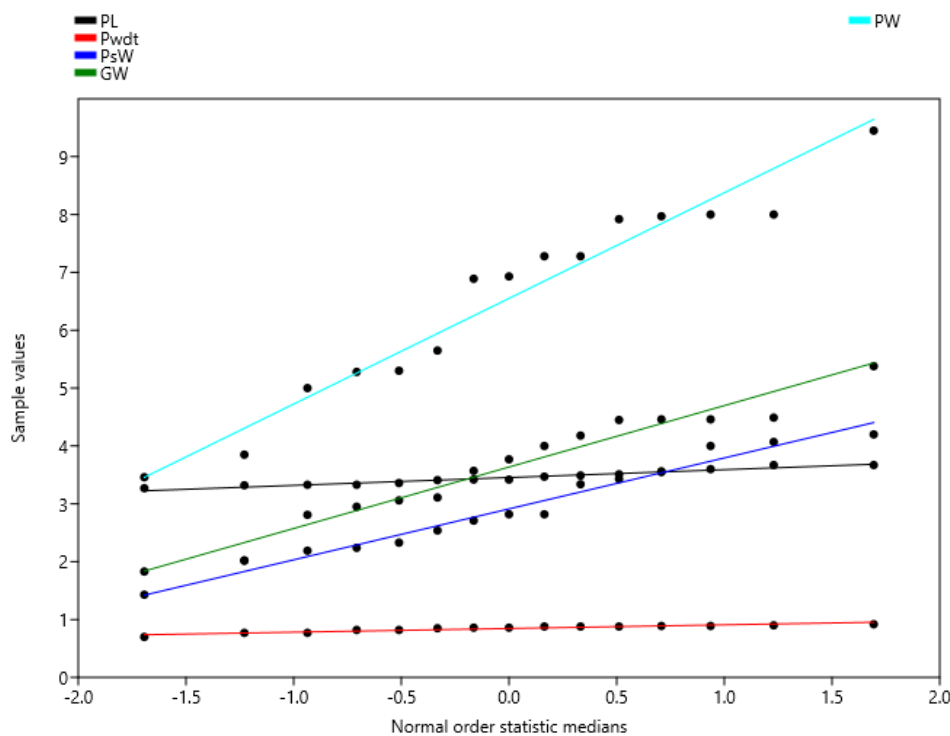


Figure 1. Graphical distribution of data series for productivity parameters in soybeans, Iris variety

The regression analysis was applied to describe through equations the yield variation (Y , kg ha^{-1}) in relation to productivity elements.

The yield variation (Y), in relation to the size of the soybean pods, was described by equation (1), under conditions of Multiple $R = 0.705$. The graphic distribution of Y values in relation to the productivity elements (PL, Pwdt) is presented in figure 2.

$$Y_{(PL,Pwdt)} = ax^2 + by^2 + cx + dy + exy + f \quad (1)$$

where: $Y_{(PL,Pwdt)}$ – soybean yield (kg ha^{-1});

x – pod length (PL, cm);

y – pod width (Pwdt, cm);

a, b, c, d, e, f – coefficients of the equation (1); $a= 27062.035378$; $b= 6641.761819$;

$c= -217270.876904$; $d= -118005.046775$; $e= 32628.479321$; $f= 428133.570818$

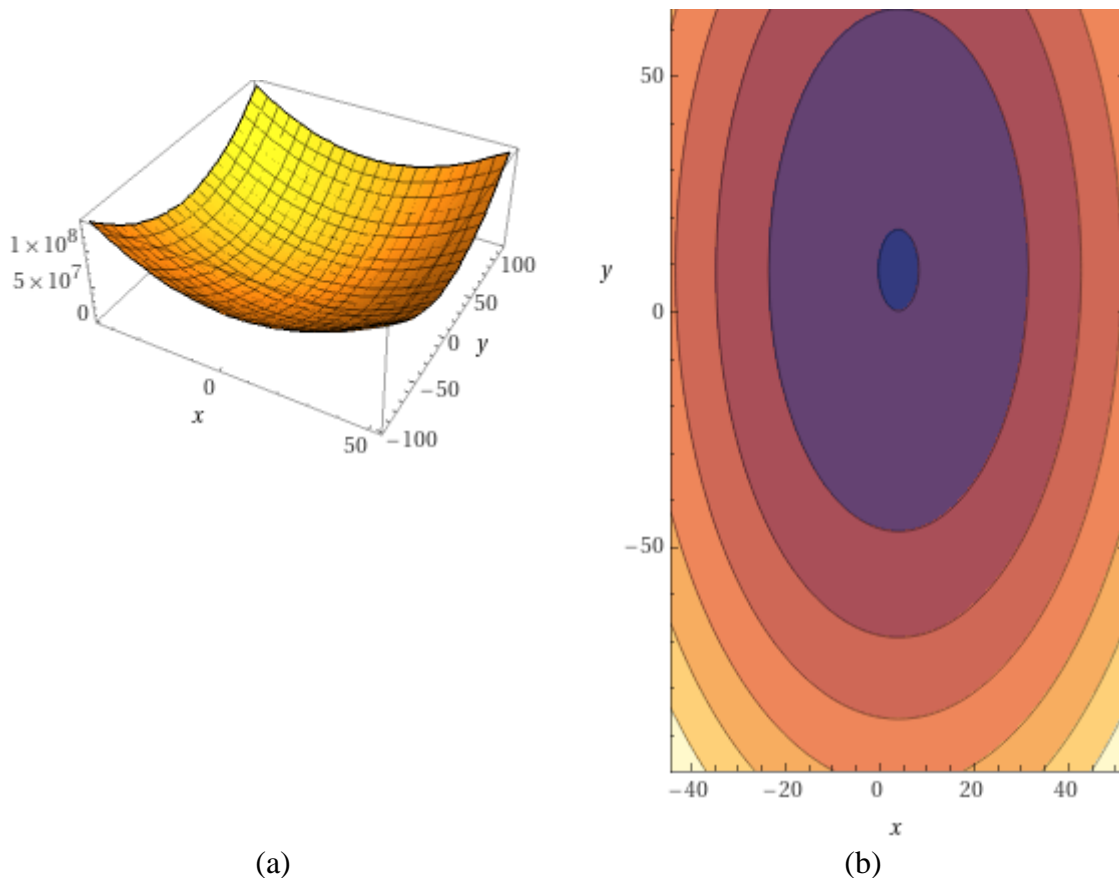


Figure 2. Graphic distribution of soybean yield, in relation to PL and Pwdt parameters

The yield variation (Y), in relation to the weight of pods and the weight of soybeans grains, was described by equation (2), under conditions of Multiple $R = 0.573$. The graphic distribution of Y values in relation to the productivity elements (PW, GW) is presented in figure 3.

$$Y_{(PW,GW)} = ax^2 + by^2 + cx + dy + exy + f \quad (2)$$

where: $Y_{(PW,GW)}$ – soybean yield (kg ha^{-1});

x – pod weight (PW, g);

y – grain weight (GW, g);

a, b, c, d, e, f – coefficients of the equation (2); $a= -705.765031$; $b= -1824.968015$;

c= 1703.554940; d= -321.109684; e= 2088.232917; f= -3652.315502

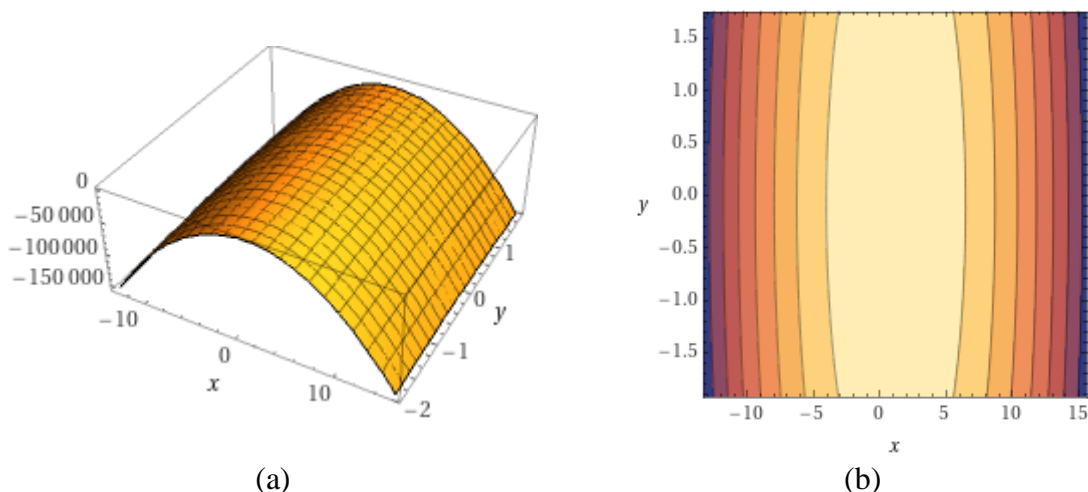


Figure 3. Graphic distribution of soybean yield, in relation to PW and GW parameters

The yield variation (Y), in relation to PW and PsW parameters, was described by equation (3), under conditions of Multiple R = 0.574. The graphic distribution of Y values in relation to the productivity elements (PW, PsW) is presented in figure 4.

$$Y_{(PW,PsW)} = ax^2 + by^2 + cx + dy + exy + f \quad (3)$$

where: $Y_{(PW,PsW)}$ – soybean yield (kg ha⁻¹);
 x – pod weight (PW, g);
 y – pod shells weight (PsW, g);
 a, b, c, d, e, f – coefficients of the equation (3); a= -444.400405; b= -1821.585184;
 c= 1399.260083; d= 251.752210; e= 1566.819438; f= -3609.562688

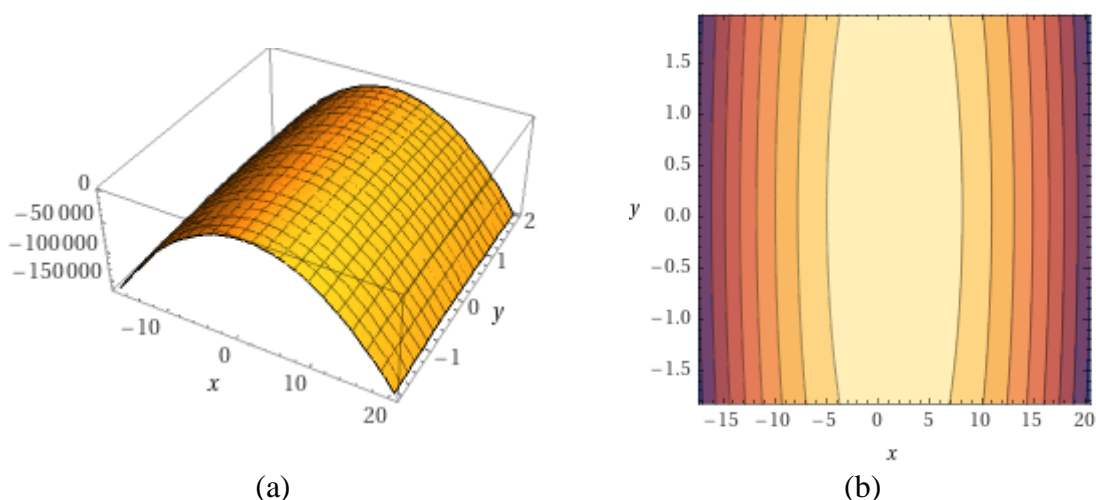


Figure 4. Graphic distribution of soybean yield, in relation to PW and PsW parameters

From the analysis of the RMSE values, it was found that the best level of yield estimation, under the study conditions, was based on the PL and Pwdt parameters (RMSEP = 492.113 kg ha⁻¹), compared to the estimation based on the PW and GW parameters (RMSEP = 568.445 kg ha⁻¹), or in the case of PW and PsW parameters (RMSEP = 568.022 kg ha⁻¹).

The estimation of biomass production, yield, or some quality indices in agricultural crops, have been described by different models, in relation to cultivated genotypes, fertilization, or other elements of technology [1,2,4,15].

Under the conditions of the present study, non-irrigated crop system, the variation of soybean yield was described in terms of statistical safety, with a margin of safety given by RMSEP between 492.113 kg ha⁻¹ and 568.445 kg ha⁻¹. This can be associated with drought, the presence of weeds in the crop.

CONCLUSIONS

The Iris soybean variety recorded specific values for productivity parameters in the experimental and climatic conditions. The data series for the analyzed parameters presented a normal distribution.

The regression analysis led to models in the form of equations, which safely described the yield variation (Y, kg ha⁻¹) in relation to the considered parameters, as a direct relationship and interaction. Based on the PL and Pwdt parameters, it was possible to estimate the yield, with a higher safety level compared to the other parameters. The safety level was also confirmed by the RMSEP parameter, which under the conditions of the PL and Pwdt parameters was RMSEP = 492.113 kg ha⁻¹.

Under the conditions of the other parameters, yield estimation was possible, but at a lower safety level, and with less precision.

ACKNOWLEDGEMENTS

The present data were generated following the implementation of the ADER 1.4.1 project.

REFERENCES

- [1]. **AGAPIE A.L., HORABLAGA M.N., VACARIU B., EREMI O., SALA F., 2024**, Biometric parameters in the characterization of ears in a collection of corn genotypes, *Life Science and Sustainable Development*, 5(1), pp. 44-51.
- [2]. **AGAPIE A.L., SALA F., 2024**, The variation of protein content in maize grains in relation to the fertilization level, *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, 22(4), pp. 31-38.
- [3]. **BELLALOUI N., BRUNS H.A., ABBAS H.K., MENGISTU A., FISHER D.K., REDDY K.N., 2015**, Agricultural practices altered soybean seed protein, oil, fatty acids, sugars, and minerals in the Midsouth USA, *Frontiers in Plant Science*, 6, 31.
- [4]. **CONSTANTINESCU C., HERBEI M., RUJESCU C., SALA F., 2018**, Model prediction of chlorophyll and fresh biomass in cereal grasses based on aerial images, *AIP Conference Proceedings*, 1978(1), 390003.
- [5]. **FENG X., YU D., BHATTACHARYYA M.K., 2022**, Editorial: Novel technologies for soybean improvement, *Frontiers in Plant Science*, 13, 1047739.
- [6]. **HAMMER Ø., HARPER D.A.T., RYAN P.D., 2001**, PAST: Paleontological Statistics software package for education and data analysis, *Palaeontologia Electronica*, 4(1), 1-9.
- [7]. **KERGES K., BELLINGRATH-KIMURA S.D., WATSON C.A., STODDARD F.L., HALWANI M., RECKLING M., 2022**, Agro-economic prospects for expanding soybean production beyond its current northerly limit in Europe, *European Journal of Agronomy*, 133, 126415.

- [8]. KEZAR S., BALLAGH A., KANKARLA V., SHARMA S., SHARRY R., LOFTON J., 2023, Response of soybean yield and certain growth parameters to simulated reproductive structure removal, *Agronomy*, 13, 927.
- [9]. KRISDIANA R., ELISABETH D.A.A., SAERI M., DARSANI Y.R., BURHANSYAH R., KILMANUN J.C., YAUMIDIN U.K., MEJAYA M.J., HARNOWO D., HARSONO A., 2024, Agribusiness analysis of seed producer supports increased soybean production in East Java production centre areas, *International Journal of Agricultural Sustainability*, 22(1), 2361581.
- [10]. MAJIDIAN P., GHORBANI H.R., FARAJPOUR M., 2024, Achieving agricultural sustainability through soybean production in Iran: Potential and challenges, *Heliyon*, 10(4), e26389.
- [11]. MEIER U., 2001, Growth stages of mono-and dicotyledonous plants e BBCH monograph, Federal Biological Research Centre for Agriculture and Forestry, 158 pp.
- [12]. OMONDI J.O., MKUHLANI S., MUGO J., CHIBEBA A.M., CHIDUWA M.S., CHIGEZA G., KYEI-BOAHEN S., MASIKATI P., NYAGUMBO I., 2023, Closing the yield gap of soybean (*Glycine max* (L.) Merril) in Southern Africa: A case of Malawi, Zambia, and Mozambique, *Frontiers in Agronomy*, 5, 1219490.
- [13]. QIN P., WANG T., LUO Y., 2022, A review on plant-based proteins from soybean: Health benefits and soy product development, *Journal of Agriculture and Food Research*, 7, 100265.
- [14]. RINALDI J., ARYA N., MAHAPUTRA I., ELISABETH D., RESIANI N., ARSANA I., SILITONGA T., 2023, Production factors, technical, and economic efficiency of soybean (*Glycine max* L. Merr.) farming in Indonesia, *Open Agriculture*, 8(1), 20220194.
- [15]. SALA F., RUJESCU C., FEHER A., 2019, Assessment model for the imbalance in N and PK fertilization for maize: Case study for the western part of Romania, *Romanian Agricultural Research*, 36, 143-153.
- [16]. VOGEL J.T., LIU W., OLHOFT P., CRAFTS-BRANDNER S.J., PENNYCOOKE J.C., CHRISTIANSEN N., 2021, Soybean yield formation physiology – A foundation for precision breeding based improvement, *Frontiers in Plant Science*, 12, 719706.
- [17]. WOLFRAM RESEARCH INC., 2020, *Mathematica*, Version 12.1, Champaign, IL (2020).