Original Research Article

Long Term Impact of Fertilization and Intensive Cropping on Maize Yield and Soil Nutrient Availability Under Sandy Clay Loam Soil (Inceptisol)

ABSTRACT

Continuous cropping and fertilization could significantly impact crop productivity and soil nutrient availability in long run. A single nutrient application or omission of nutrient or mineral fertilizer alone can deteriorate the soil nutrient availability and yield in long run. The use of balanced fertilizers either alone or integrated with organic manure (FYM) has significantly increased the grain and straw yield of maize. The yield increment of maize was observed 13.9 per cent higher than 100% NPK and 18.3 percent higher than without the addition of S (S free). Balanced fertilization can improve the soil nutrients (N, P, K & S) and soil organic carbon instead addition of FYM @ 10 t ha^{-1} could increase the SOC and soil nutrients in long run in a sustainable manner. Concerning nitrogen, single nutrient (N alone) plots received low available nutrients and yield also it's deteriorated the soil nutrients over long period. A build-up of available soil P and S was observed due to its continuous addition through fertilizer but soil K has reduced because of intensive cropping and high-yielding cultivars. Hence, for sustainable production, application of a recommended dose of mineral fertilization (100% NPK) along with FYM @ 10 t ha^{-1} may be used to achieve a higher yield, stable nutrient balance and soil quality over decades.

Keywords: Maize yield, Soil properties, ~~Long~~long term fertilization, Soil Health, and Sustainable Agriculture

1. INTRODUCTION

The use of high-analysis fertilizers to improve crop yield potentials rapidly cast a shadow on the usage of organic manures. This has an impact on soil parameters and the ecosystem, as well as the long-term viability of agricultural production levels [1]. Soil quality is the most important functional component in determining crop production potential. The Integrated Nutrient Management system (INM) is used in cropping systems to solve this challenge. The INM's core principle is to preserve soil fertility for long-term agricultural production while simultaneously lowering fertilizer input costs. Various organic manures, such as FYM, vermicompost, green manuring, and agricultural waste recycling, are currently being used to replace inorganic fertilizers.

Integrated nutrient management can help to conserve the environment while also ensuring long-term crop yields. This will be a noble organic agricultural strategy. The combined effect of nutrient input, synergism, and improvement in soil physical and biological features, as well as crop physiological processes, may explain why Integrated Nutrient Management (INM) has demonstrated its promise in enhancing crop yield. As a result, it has been recognized that an assessment of crop-specific land quality is required to identify yield-decreasing variables. [2] emphasized the need of developing a land quality that is independent of the kind of land use.

Long-term monitoring enables both detection and prediction of existing and future changes in the soil [3]. Even though inorganic fertilizers are widely known for their ability to sustain or boost agricultural yields, their application might change the physical, chemical, and biological properties of soil. These long-term changes are thought to have a substantial impact on the soil's quality and productivity [4].

According to several researches, soil nutrients are the major yield-limiting factors. Exogenous fertilization influences crop yields by improving soil fertility, such as soil carbon, nutrients, and pH. Soil carbon content is the essential index for different yields. Therefore, to achieve high crop productivity, it is important to understand the impact of different fertili zer inputs on crop yields. The application of manure could provide not only carbon but also different nutrients for crop uptakes. The crop residual effect of manure application was visible after many years, leading to higher nutrient availability for crop growth [5]. In this context, knowledge is scarce on the long-term impacts of inorganic fertilizer and manure application on soil properties and crop productivity, particularly in India.

2. MATERIAL AND METHODS

2.1 Site description

The current study was conducted as part of a long-term fertilizer experiment that was started by ICAR- All India Coordinated Research Project (AICRP) in 1972 and is being managed by the Department of Soil Science and Agricultural Chemistry at Tamil Nadu Agricultural University, Coimbatore in Field no.36 F, Eastern block farm with Finger millet – Maize cropping sequence. The study area is located at 11° North latitude, 77° East longitude, with a height of 426.7 meters above Mean Sea Level (MSL). The experimental soil belongs to classified as Inceptisol (*Vertic Ustropept*), with calcareous mixed black soil and sandy clay loam texture, and Periyanaickenpalayam series.

2.2 Design of the experiment and treatment structure

The experiment is being conducted with ten treatments and four replications the plots are randomized by Randomised Block Design (RBD) under finger millet (Kharif) – maize (rabi) cropping sequence. Instead, in the present investigation, ten treatments with three replicated plots are taken and the test crop was maize (113th crop). The treatments are as follows; 50% NPK (T_1), 100% NPK(T_2), 150% NPK(T_3), 100% NPK + Hand Weeding (T_4), 100% NPK + Zinc (T_5), 100% NP (T_6), 100% N (T_7), 100% NPK + FYM (T_8), 100% NPK (Sulphur free source) (T_9) along with absolute control(T_{10}).

The recommended dose of N, P_2O_5, and K_2O for maize crop has used as 250, 75, and 75 kg ha^{-1} respectively. At the time of sowing, a half dosage of N and a full dose of P and K were administered. The other half of the nitrogen was applied in two equal splits to the maize crop at the knee-high and pre-tasselling phases. Urea, Single Super Phosphate (SSP), and Muriate of Potash were used as N, P, and K sources for all treatments except T_9 (S free - DAP as P source), and hand weeding was done for T_4 (100% NPK + hand weeding). For INM (100% NPK + FYM) plots received 10 t ha^{-1} of FYM (1.01%, 0.26% & 0.40% of N, P, and K) for every crop.

2.3 Soil sampling and analysis

The representative soil samples were taken from the surface soil of each plot and used of quartering technique to get a composite soil sample. The composite soil samples were air-dried, mashed using a wooden pestle and mortar, and then passed through a 2 mm screen before being used to test various physical and chemical parameters.

2.3.1 Soil physico-chemical properties

The soil pH and electrical conductivity (EC) were measured by a glass electrode pH meter and EC meter in 1:2.5 soil: water suspension [6].

2.3.2 Soil chemical properties

The organic carbon content of the soil was determined by the modified Walkley black method [7] as described by [8]. Available nitrogen in the soil was determined by the alkaline permanganate method [9] . Available phosphorus in soil was determined by Olsen's method [10] as described by [8]. Available potassium in soil was determined by the neutral normal ammonium acetate (NH_4OAc) method as described by [8]. Soil available sulphur was extracted with a 0.15% solution of $CaC1_2$ and determined by the turbidimetric method [11]. The details of the initial physico chemical properties were presented in Table 1.

2.4 Statistical analysis

The data obtained from the experiments are analyzed for their significance (p=0.05) by statistical procedure appropriate for randomized block design as outlined by [12].

3. RESULTS AND DISCUSSION

3.1 Effect of ~~long term~~long-term fertilization and intensive cropping on grain yield of maize (kg ha^{-1})

The ~~long term~~long-term fertilization has significantly increased the grain yield and straw yield of maize under sandy clay loam soil. Irrespective of the treatments, the progressive increases of grain yield with increase in the dose of NPK fertilizers from 50 % NPK to 150 % NPK. The highest grain yield of maize was recorded in INM plot (100% NPK + FYM@ 10 t ha^{-1}) of kg ha^{-1} which was 13.9 per cent yield increases than 100% NPK plots (Table 2). Continuous application of N alone plots got declined the yield than plots which received recommended dose of ~~fertiliser~~fertilizer (T_2 - T_5), NP and 50% NPK treated plots. The lowest grain and straw yield of maize was recorded in control plots of 2723 and 4410 kg ha^{-1} respectively. This was due to the impact of addition of FYM could added the quantum of nutrients as well organic matter to the soil and these organic matter increases the microbial activities in soil [13]. Recommended dose of applied NPK ~~fertilisers~~fertilizers could meet out the primary nutrients as well secondary nutrient of S for complete the cropping cycle. Combined application of both organics (FYM @ 10 t ha^{-1}) as well mineral ~~fertilisers~~fertilizers could increases the yield, productivity and soil health in sustain manner [14] [15]

3.2 Effect of ~~long term~~long-term fertilization and intensive cropping on soil physico chemical properties in maize crop

3.2.1 Soil reaction (pH) and Electrical Conductivity (EC) (d Sm^{-1})

Since 1972, the soil reaction (pH) and EC was changes slightly by the continuous use of mineral fertilizer and organic manures. At present, the soil reaction may ~~ranged~~range from 8.53 to 8.72 (Table 3), indicating that there was no significant impact on the pH of the soil, which might be related to the soil's strong buffering capacity [16]. Similarly, the EC of soil did not vary significantly over time due to the continual administration of fertilizers in almost all the treated plots. In the soil, the EC varied from 0.51 to 0.62 dS m^{-1}. This might be related to the unique properties of black soils, which have a high buffering capacity by nature [17].

3.3 Effect of ~~long term~~long-term fertilization and intensive cropping on soil chemical properties in maize crop

3.3.1 Soil Organic Carbon (g Kg^{-1})

Soil organic carbon is an important biochemical property which drives for nutrient transformation in soil. Initially, this experiment recorded the 3 g kg^{-1} (0.3%) since 1972 and the SOC content was progressively increased from 3 g kg^{-1} to 7.7 g kg^{-1} by practicing various nutrient management practices over 49 years of intensive cropping (Table 3). SOC has significantly increased progressively as the doses of fertilizer increased from 50 % NPK to 150% NPK (5.5 to 6.5 g kg^{-1}). This due to the addition of nutrients increased the root biomass and plant residues which build up the SOC in soil in long run[18]. Irrespective of the nutrient management practices, 100% recommended dose of fertilizer along with FYM @ 10 t ha^{-1} recorded the highest SOC of 7.7 g kg^{-1} followed by 150 per cent NPK (6.5 g kg^{-1}) plot. Addition of quantum of FYM drives a sole factor for nutrient cycling and nutrient transformation in soil. Theses effective catalyst may induce the proper microbial growth and nutrient availability for plant growth by increasing the SOC [19, 20]. Other plots which received recommended dose of nutrients such as T_2 to T_5 and T_7 plots are on par with each other and the lowest in control plot of 4.2 g kg^{-1} SOC in maize crop.

3.3.2 Soil Available Nutrients (N, P, K & S)

Soil primary nutrients are important for plants to complete their life cycle and the initially the NPK and S nutrients was noted that N @ 178, P @ 11 and K @ 819 kg ha^{-1}. Continuous farming and practicing various nutrient management practices showed the increases of NPK and S over the years (Table 3).

In soil nitrogen, INM (100% RDF along with FYM @ 10 t ha^{-1}) showed the highest soil N of 247 kg ha^{-1} which was 20.7% higher than 100% NPK plot. The increases of fertilizer doses from 50 to 150% could observe the higher N from 170.6 to 233.5 kg ha^{-1} and other treatments are on par with each other. Adding N alone plots showed the deterioration of N than other plots and lowest N was observed in control plot (156.8 kg ha^{-1}). Application of chemical fertilizer along with FYM alone could increase the biological activities like microbial stabilization and root growth etc. may reason for high N than chemical fertilizer alone. However, the addition of suboptimal, optimum, and super optimal fertilizer dosages of fertilizer N leads for boosted of N content and enrichment of N pools [21] in soil.

Similarly, soil P also noted same trend like addition of balanced fertilization (manure plus mineral fertilizers) or super optimal fertilizer increases the P status in soil. The P content was ranged from 8.8 to 28.8 kg ha^{-1} and the significant P content has noted in INM plot of 28.8 kg ha^{-1} followed by 150% NPK (27.9 kg ha^{-1}) and lowest in control plot of 8.8 kg ha^{-1}. This was the result of application of FYM could increases P mineralization rate when the plant demanding the root development and grain production [22].

The experimental soil belongs to vertic ustropept and have the high soil K status since starting of the experiment and the soil K could depleted by using high yielding cultivars and high analyzing fertilizers. The soil available K was ranged from 542 to 795 kg ha^{-1} and the content of soil K has increase by the increased dose of fertilizers. The available K was significantly higher in the treatment receiving the regular application of K fertilizer compared to the treatments with the omission of K fertilizer viz., absolute control and 100 % NP. This might be due to the exploitation of soil K reserves to meet the crop needs.

INM (100% NPK + FYM @ 10t ha^{-1}) showed highest soil available K of 795 kg ha^{-1} followed by 150% NPK of 711 kg ha^{-1} and lowest in control (543 kg ha^{-1}) in maize crop. The reason for increased availability of K in 100 % NPK + FYM treatment might be due to the direct addition of K from FYM and also FYM limits the fixation of K in soil and enhances the release of fixed K by contact of organic matter with clay [23]

Sulphur is an important secondary nutrient in which application of sulphur source single super phosphate could increases the S availability in soil. Sulphur addition may induce the rapid mineralization of S in soil to meeting the S demand in soil. The significant higher available S was noted in INM plot (36.2 mg kg^{-1}) followed by150% NPK (35.0 mg kg^{-1}) in soil. This could be due to the release of organic acids during the decomposition of organic matter, resulting in the resolution of both applied and native S into available S compounds, increasing the activity and concentration of available S in soil [16] . The available SO_4^{2-} - S content was found high in recommended dose of fertilizers 100 % NPK (Used P as SSP) (18.33 mg kg^{-1}) than 100% NPK (S free). This is due to the application of sulphur free fertilizers (DAP) fail to improve the soil S status.

The grain yield of maize was positively correlated with SOC, soil N, P K and S and it has highly correlated with soil P. It is ~~a~~an established fact that, yield ~~are~~is highly dependent with soil nutrient SOC and especially soil P (Table 4).

It is necessary to discuss these results, with emphasis on the causes of the matter. Therefore I recommend citing the scientific manuscripts.

It is interesting to note that the Sorghum and finger millet (Kharif) are crops that requires less water than ~~corn~~maize, for this reason it has potential as a forage plant that can be grown in this region, since in addition its nutritional value is equal to or slightly higher compared to corn, and with a productive response superior [24, 25]. Despite the above, and in particular under semi-arid conditions in the study area, the species by itself cannot guarantee high yields, so it is necessary to accompany its sowing with adequate in situ water catchment practices. of rain, which have implicit techniques that, in addition to making better use of rain (because it increases the amount of water available to plants) [26, 27, 28], followed by practices that help conserve the soil, with the consequent benefits [29, 30, 31].

Certain environmental characteristics of the region under study determine that during the day there are high temperatures and during the night cooler (lower), which, for a C-4 photosynthesis type species such as sorghum, is extremely important for the production of matter. dry, since there are temperatures within the optimal during the day for photosynthesis, and on the other hand, low temperatures at night reduce respiratory rates and consequently the production of dry matter is more efficient [32, 33, 34], this added to the edaphic factors not studied in this research may have a direct effect on the grain and straw yield of maize, as reported by studies oriented to the influence of soil conditions in productivity in environments like the one in our study [35, 36].

4. CONCLUSION

By practicing various nutrient managements, application of balanced application of fertilizers and manures could improve the yield, productivity over longer period. The use of sub optimal, optimal and over optimal use of fertilizers ~~drive~~drives the addition or depletion of nutrients in soil. Intensive cropping with use of high analyzing fertilizers and high yielding cultivars may deplete the nutrient and productivity would be declined when applying sub optimal dose, omission of nutrients or use of single nutrients over years. ~~So~~So, the present study clearly indicated that the use of nutrients in integration of manures (FYM @ 10 t ha^{-1}) along with recommended dose of fertilizers may improve the yield and soil nutrients in sustained manner.

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Table.1 Initial physico-chemical properties of experimental soil (1972)

Characteristics of Soil	(1972) Value
Particle size analysis	
Clay (%)	32.6
Silt (%)	11.8
Fine sand (%)	15.1
Coarse Sand (%)	39.4
Soil textural class	Sandy clay loam
Physicochemical and chemical analysis	
pH (1:2.5 soil: water suspension)	8.20
Electrical conductivity (dS m^{-1})	0.20
Organic carbon (%)	3.0
Cation exchange capacity [c mol (p+) kg^{-1}]	25.5
Available nitrogen (kg N ha^{-1})	178.0
Available phosphorus (kg ha^{-1})	11.0
Available potassium (kg ha^{-1})	810.0
Available Sulphur (mg kg^{-1})	12.2

Table 2. Effect of continuous cropping and fertilization on grain and straw yield of maize

Treatments	**Grain Yield**	**Straw Yield**
	(kg ha^{-1})	
50 % NPK	4972	6483
100 % NPK	5461	8030
150 % NPK	5482	8152
100 % NPK + HW	5142	7656
100 % NPK + Zn	5373	8257
100 % NP	5151	8201
100 % N	3910	6332
100 % NPK + FYM	6348	9401
100 % NPK (-S)	5189	7821
Control	2723	4410
SEd	134	188
CD (p=0.05)	282	397

Table 3. Effect of ~~long term~~long-term fertilization and intensive cropping on soil physico chemical properties in maize crop

Treatments	pH	EC (dSm^{-1})	SOC ($g\ kg^{-1}$)	Soil N	Soil P	Soil K	Soil S ($mg\ kg^{-1}$)
				($Kg\ ha^{-1}$)			
50 % NPK	8.58	0.571	5.5	171	20.7	579	14.4
100 % NPK	8.68	0.617	6.3	196	23.2	686	18.3
150 % NPK	8.85	0.636	6.5	234	27.9	711	35.0
100 % NPK + HW	8.64	0.562	6.4	199	22.5	684	17.1
100 % NPK + Zn	8.65	0.612	6.1	216	23.2	645	20.6
100 % NP	8.60	0.559	5.9	200	20.1	565	16.8
100 % N	8.46	0.552	5.0	187	12.3	576	11.0
100 % NPK + FYM	8.72	0.625	7.7	248	28.8	795	36.2
100 % NPK (-S)	8.75	0.571	6.2	204	23.0	624	8.9
Control	8.53	0.51	4.2	157	8.8	543	7.3
SEd	NS	NS	0.49	16.6	1.78	51.2	0.71
CD (p=0.05)	0.34	0.023	0.23	7.90	0.85	24.4	0.33

Table 4. Correlation of maize grain yield with soil physicochemical properties in soil

Parameters	Yield	SOC	Soil N	Soil P	Soil K	Soil S
Yield	1					
SOC	0.93**	1				
Soil N	0.81**	0.89**	1			
Soil P	0.94**	0.93**	0.84**	1		
Soil K	0.79**	0.90**	0.85**	0.82**	1	
Soil S	0.78**	0.78**	0.86**	0.79**	0.84**	1

** Correlation is significant at the 0.01 level (2-tailed**)**

REFERENCES

1. Khandagle, A., et al., *Effect of long-term application of fertilizers and manure on soil properties.* Journal of Soils and Crops, 2019. **29**(1): p. 97-104.
2. Karlen, D.L., et al., *Soil quality: a concept, definition, and framework for evaluation (a guest editorial).* Soil Science Society of America Journal, 1997. **61**(1): p. 4-10.
3. Antil, R.S. and M. Singh, *Effects of organic manures and fertilizers on organic matter and nutrients status of the soil.* Archives of Agronomy and Soil Science, 2007. **53**(5): p. 519-528.
4. Gholamhosseinian, A., M.H. Bashtian, and A. Sepehr, *Soil Quality: Concepts, Importance, Indicators, and Measurement*, in *Soils in Urban Ecosystem*. 2022, Springer. p. 161-187.
5. Cai, A., et al., *Soil fertility and crop yield after manure addition to acidic soils in South China.* Nutrient cycling in agroecosystems, 2018. **111**(1): p. 61-72.
6. Piper, C. S. "Soil and plant analysis.,(Hans Publishers: Bombay, India)." (1966).
7. Walkley, A. and I.A. Black, *An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method.* Soil science, 1934. **37**(1): p. 29-38.
8. Jackson, M., *Soil chemical analysis prentice.* Hall of India Private Limited, New Delhi, 1967. **498**(1).
9. Subbaiah, B., *A rapid procedure for estimation of available nitrogen in soil.* Curr. Sci., 1956. **25**: p. 259-260.
10. Olsen, S.R., *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. 1954: US Department of Agriculture.
11. Chesnin, L. and C. Yien, *Turbidimetric determination of available sulfates.* Soil Science Society of America Journal, 1951. **15**(C): p. 149-151.
12. Gomez, K.A. and A.A. Gomez, *Statistical procedures for agricultural research*. 1984: John wiley & sons.

13. Parewa, H.P. and J. Yadav, *Response of fertility levels, FYM and bioinoculants on yield attributes, yield and quality of wheat.* Agric Sustain Dev, 2014. **2**(1): p. 5-10.
14. Cavagnaro, T.R., et al., *The role of arbuscular mycorrhizas in reducing soil nutrient loss.* Trends in Plant Science, 2015. **20**(5): p. 283-290.
15. Kumar, R.R., et al., *Effect of Integrated Nutrient Management on yield of maize crop under rainfed condition in eastern part of uttarpradesh, India.* Int. J. Curr. Microbiol. App. Sci, 2018. **7**(9): p. 21-34.
16. Suman, J., et al., *Impact of continuous addition of fertilizers and manures on soil nutrient status, uptake, protein and oil content of soybean in a Vertisol.* Research Journal of Agricultural Sci, 2017. **8**(1): p. 159-163.
17. Dwivedi, A. and B. Dwivedi, *Impact of long term fertilizer management for sustainable soil health and crop productivity: Issues and challenges.* Volume: 49 Research Journal, 2015. **49**(3): p. 374.
18. Chaudhary, S., G. Dheri, and B. Brar, *Long-term effects of NPK fertilizers and organic manures on carbon stabilization and management index under rice-wheat cropping system.* Soil and Tillage Research, 2017. **166**: p. 59-66.
19. Dhaliwal, S., et al., *Dynamics and transformations of micronutrients in agricultural soils as influenced by organic matter build-up: A review.* Environmental and Sustainability Indicators, 2019. **1**: p. 100007.
20. Krasilnikov, P. and M.A. Taboada, *Fertilizer Use, Soil Health and Agricultural Sustainability*. 2022, MDPI. p. 462.
21. Bairwa, J., et al., *Long-term effect of nutrient management on soil microbial properties and nitrogen fixation in a vertisol under soybean–wheat cropping sequence.* Journal of the Indian Society of Soil Science, 2021. **69**(2): p. 171-178.
22. Kalaiselvi, K., et al., *Effect of long term fertilization on phosphorus dynamics in root zone environment under finger millet-Maize cropping sequence.* Journal of Applied and Natural Science, 2021. **13**(4): p. 1383-1389.
23. Urkurkar, J., et al., *Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (Oryza sativa) and wheat (Triticum aestivum) in Inceptisols.* Indian Journal of Agricultural Sciences, 2010. **80**(3): p. 208-212:
24. Bertorelli M, Olivares B.O. Population fluctuation of Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) in sorghum cultivation in Southern Anzoategui, Venezuela. Journal of Agriculture University of Puerto Rico. 2020; 104(1):1-16. https://doi.org/10.46429/jaupr.v104i1.18283
25. Olivares B, Hernández R, Arias A, Molina JC, Pereira Y. Zonificación agroclimática del cultivo de maíz para la sostenibilidad de la producción agrícola en Carabobo, Venezuela. Revista Universitaria de Geografía. 2018; 27 (2): 139-159. https://n9.cl/i0upn
26. Olivares B. Tropical conditions of seasonal rain in the dry-land agriculture of Carabobo, Venezuela. La Granja: Journal of Life Sciences. 2018; 27(1):86-102. http://doi.org/10.17163/lgr.n27.2018.07
27. Olivares B, Parra R, Cortez, A. Characterization of precipitation patterns in Anzoátegui state, Venezuela. Ería. 2017; 3 (3): 353-365. https://doi.org/10.17811/er.3.2017.353-365
28. Olivares B. Description of soil management in agricultural production systems of sector Hammock in Anzoátegui, Venezuela. La Granja: Revista de Ciencias de la Vida. 2016; 23(1): 14–24. https://doi.org/10.17163/lgr.n23.2016.02
29. Olivares B, Cortez A, Parra R, Lobo D, Rodríguez M.F, Rey JC. Evaluation of agricultural vulnerability to drought weather in different locations of Venezuela. Rev. Fac. Agron. (LUZ) 2017; 34 (1): 103-129. https://n9.cl/d827w
30. Olivares B, Hernández, R; Coelho, R., Molina, JC., Pereira, Y. Análisis espacial del índice hídrico: un avance en la adopción de decisiones sostenibles en los territorios agrícolas de Carabobo, Venezuela. Revista Geográfica de América Central. 2018; 60 (1): 277-299. https://doi.org/10.15359/rgac.60-1.10
31. Olivares, B., Hernández, R; Coelho, R., Molina, JC., Pereira, Y. 2018. Analysis of climate types: Main strategies for sustainable decisions in agricultural areas of Carabobo, Venezuela. Scientia Agropecuaria. 9(3): 359 – 369. https://doi.org/10.17268/sci.agropecu.2018.03.07
32. Olivares B, Paredes F., Rey, J., Lobo, D., Galvis-Causil, S. The relationship between the normalized difference vegetation index, rainfall, and potential evapotranspiration in a banana plantation of Venezuela. SAINS TANAH - Journal of Soil Science and Agroclimatology, 2021; 18(1), 58-64. http://dx.doi.org/10.20961/stjssa.v18i1.50379
33. Olivares, B., Hernández, R. Regional analysis of homogeneous precipitation areas in Carabobo, Venezuela. Revista Lasallista de Investigación. 2019; 16(2):90-105. https://doi.org/10.22507/rli.v16n2a9

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34. Casana S, Olivares B. Evolution and trend of surface temperature and windspeed (1994 - 2014) at the Parque Nacional Doñana, Spain. Rev. Fac. Agron. (LUZ). 2020; 37(1):1-25.

35. Olivares BO, Calero J, Rey J.C, Lobo D, Landa BB, Gómez J. A. Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. Catena, 2022; 208: 105718. https://doi.org/10.1016/j.catena.2021.105718

36. Olivares B, Araya-Alman M, Acevedo-Opazo, C. et al. Relationship Between Soil Properties and Banana Productivity in the Two Main Cultivation Areas in Venezuela. J Soil Sci Plant Nutr. 2020; 20 (3): 2512-2524. https://doi.org/10.1007/s42729-020-00317-8

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