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Title

Effect of tillage systems combined with plant residue management and Potassium fertilizer application on agronomic characteristics, energy budgeting and emergy based indices of roselle *(Hibiscus sabdariffa)*

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Abstract
This study was conducted to evaluate the effect of tillage systems combined with plant residue management and the application of potassium fertilizer on the agricultural characteristics, energy components and emergy indices of the medicinal plant of Roselle (*Hibiscus sabdariffa* L.). A split plot-factorial design trial based on a randomized complete block design (RCBD) with three replications was conducted at the research field of Agricultural Research Institute University of Zabol during the ۲۰۱۷-۲۰۱۹ crop years. The main factor was three levels of tillage system (zero (without plowing), reduced (disk) and conventional tillage (disc + plow)) and the secondary factor was the combination of plant residues at three levels (zero, ۳۰ and ٦۰٪) with potassium sulfate fertilizer at three levels (no fertilizer, ۷۵ and ۱۵۰ kg/ha) were considered. The studied traits were measured as follows: agricultural characteristics (sepal yield (sepal dry weight), biological yield, harvest index, chlorophyll a, b and carotenoid, anthocyanins, flavonoids, protein, etc.), energy components (input and output energy, direct and indirect energy, renewable and non-renewable energy, energy efficiency and productivity, and pure energy) and emergy indices (conversion coefficient of economic and biological yield, special emergy for economic and biological yield, emergy renewable percentage, emergy performance ratio, standard and modified emergy investment ratio, environmental load ratio, emergy stability index). The results showed that the interaction of tillage systems, plant residues and potassium sulfate was significant in all the investigated traits, except harvest index. The highest economic yield (sepal yield) of roselle was equal to ۲۹۱۸,۲ kg/ha in the triple interaction of the reduced tillage system with ٦۰٪ of crop residues and ۱۵۰ kg/ha of potassium sulfate, which showed more than ۱۰۰٪ increase compared to the control. The highest amount of sepal anthocyanin was obtained from no tillage treatment and combined use of ٦۰٪ plant residues and ۱۵۰ kg/ha of potassium sulfates (۲,۳۵ µmol/g SFW). Conventional tillage and combined use of ٦۰٪ residues and ۷۵ kg/ha of potassium sulfate increased chlorophyll a (۸,۰۲ mg/g) and carotenoids (۲,۵٤ mg/g). Also, reduced tillage and combined use of ۳۰٪ residues and ۷۵ kg/ha of potassium sulfate treatments increased the amount of flavonoids (۲۷,۸۸ mg/g SFW) and Conventional tillage and combined use of ۳۰٪ residues and ۷۵ kg/ha of potassium sulfate increased protein of the branches (٤۷۱,۱۱ mg/g SFW). Among the input energies, the highest and lowest input energy percentages were related to irrigation water input (٤۰,۹۷٪) and human power (۵,۲۵٪), respectively. In total, ۷٤٦۸ MJ/ha input energy and ۱۵۰٤۱,۲۸ MJ/ha output energy were related to economic (۲۵,۰۳) and biological (۷٤,۹۷) yield, respectively. The contribution of direct, indirect, renewable and non-renewable energy from the total input energy was ٤٦,۲۲, ٤۷,۵۸, ۵۲,٤۲ and ٤۷,۵۸٪, respectively. It is noteworthy that the energy efficiency, pure energy and productivity amounts were calculated at ۲,۰۱, ۷۵۷۳,۲۸ MJ/ha and ۰,٦۸ kg/MJ, respectively, in the cultivation of roselle (sour tea). In the emergy indicators, the highest and lowest percentages of emergy renewable were related to the (without plowing treatment and combined use of ٦۰٪ plant residues and no potassium sulfate fertilizer) and (conventional plowing treatment, and combined use of ۱۵۰ kg/ha potassium sulfate and no plant residues), respectively. In the index of emergy performance ratio, the highest and lowest ratios were observed in the (conventional tillage treatment and no plant residues and potassium sulfate fertilizer) and (without plowing treatment and combined use of ٦۰٪ plant residues and no potassium sulfate fertilizer), respectively. The (reduced plowing treatment and combined use of no plant residues and no potassium sulfate fertilizer) and (conventional plowing treatment and combined use of ٦۰٪ plant residues and ۱۵۰ kg/ha potassium sulfate) had the highest and lowest stability index of emergy, respectively. The results showed that the combined application of tillage systems (reduction and conventional) combined with plant residue management (٦۰ and ۳۰٪) and the application of potassium sulfate fertilizer (۱۵۰ and ۷۵ kg/ha) not only helps to reduce environmental pollution but also plays an effective role in increasing the yield and physiological characteristics of the roselle (sour tea) in Sistan region.

Keywords: Anthocyanin, Agroecosystems, Emergy analysis, Reduced tillage, Carotenoids, Conservation agriculture