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# Evaluation of Sequential Cropping System on the Yield and Energetics of Rice Followed by Cassava Intercropped Groundnut and Cowpea

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## ABSTRACT

A field experiment was conducted at the Instructional farm, College of Agriculture, Vellayani, Kerala, India during 2013 to 2015, to study the effect of methods of planting, weed and nutrient management on rice (*Oryza sativa* L.) and its effect on the succeeding cassava (*Manihot esculenta* L.) intercropped with groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* L.) in uplands. The experiment was laid out in split plot design, comprising three main plots having methods of planting [broadcasting of sprouted seeds, dibbling (sprouted seeds with drum seeder along with weeding by power weeder) and dibbling (sprouted seeds with drum seeder along with stubble mulching)] and five sub plots with methods of nutrient application [broadcasting (60-30-30 kg NPK/ha), band placement (60-30-30 kg NPK/ha), foliar spray of complex foliar fertilizer 19-19-19 @ 0.5%, foliar spray of diammonium phosphate (DAP) and sulphate of potash (SOP) each @ 2%, control] with five replications. For cassava intercropped with groundnut and cowpea recommended dose of fertilizer along with 0.5 % foliar spray of 19-19-19 was applied at 30 and 14 days interval respectively. The results revealed that the yield of succeeding crops as well as rice equivalent yield of the cropping system (29.71 t/ha) was significantly increased by the method of planting of rice using drum seeder + stubble mulching @ 3 t/ha along with either broadcasting of 60-30-30kg NPK/ha or foliar spray of diammonium phosphate (DAP) and sulphate of potash (SOP) each @ 2% applied to rice. Direct and residual effect of stubble mulching @ 3 t/ha as well as power weeding along with either soil application of 60-30-30 kg NPK/ha as broadcasting to rice or foliar spray of DAP and SOP each @ 2% to rice was found to be the energy efficient and sustainable rice-based cropping system in upland.

***Key words***: Methods of planting, Nutrient management, Energetics, System productivity, Cropping system

Rice is one of the most important cereal crops and provides food security and livelihood for millions of people across the globe. It has been estimated that almost two-thirds of the upland rice area is in Asia. Among many factors, method of sowing, seed rate, integrated nutrient management etc., influence the crop yield under upland situations. Cropping systems research has shown that short duration (5-6 months) cassava varieties can be grown successfully in a rice- based cropping system. Since the development of cassava in initial stages is very slow, a short duration crops such as groundnut can be incorporated. A legume like cowpea in rice-based cropping system either as a substitute or in a sequence enriches the soil due to their capability to fix atmospheric nitrogen. It is expected that nearly 3 million ha area of rice fallows can be brought under cultivation, which can provide about 1.5 – 2 mt of additional food grain production and help in meeting increasing demands of pulses and oilseeds [1]. Foliar formulations are gaining importance in crop production owing to its quick response in plant growth. Energetics approach in cropping system is comparatively new and research efforts in this field gathered momentum through seventies due to global fossil fuel crisis. Agriculture in a way is an energy conversion industry [2]. Inclusion of suitable crops in diversification would reduce the energy production as they are poor converters of it. Therefore, suitable cropping systems need to be designed so that apart from higher productivity and profitability, it must be efficient converter of energy. With this background, the present study was undertaken to evaluate the residual impact of methods of planting along with weed and nutrient management on the yield and energetics of rice based sequential cropping system in uplands.

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## MATERIALS AND METHODS

The experiment was conducted at the Instructional farm, College of Agriculture, Vellayani, Kerala during August 2013 to August 2015. The site is situated at 8° 25’ 46.94” N latitude and 76°59’1.12” E longitude and at an altitude of 3 m above mean sea level A total rainfall of 1518.1 mm and 2236.5 mm was recorded during the cropping period of first and second year respectively. The soil of the experimental site was sandy clay. The sequential cropping system consisted of rice succeeded by cassava (intercropped with groundnut) and cowpea. The investigation was carried out in split plot design with five replications. The three main plot with combinations of methods of planting and weeding [broadcasting of sprouted seeds, dibbling (sprouted seeds with drum seeder along with weeding by power weeder) and dibbling (sprouted seeds with drum seeder along with stubble mulching)] and the five sub plot included methods of fertilizer application [broadcasting (60-30-30 kg NPK/ha), band placement (60-30-30 kg NPK/ha at 10 DAP, tillering and panicle initiation stage), foliar spray of 19-19-19 @ 0.5% (at tillering, panicle initiation and flowering stage), foliar spray of diammonium phosphate and sulphate of potash each @ 2% (at tillering, panicle initiation and flowering stage), absolute control (without any fertilizer and organic manure)] for upland rice. FYM @ 5 t/ha was applied as basal uniformly except absolute control at the time of land preparation. Urea, mussorie rock phosphate and muriate of potash were applied to the respective plots as per the treatments to supply N, $P_2O_5$ and $K_2O$. Weeding using power weeder was done at 20 and 40 DAS. Stubble mulching was done using paddy straw @ 3 t/ha.

Recommended dose of nutrients such as FYM @ 12.5 t ha$^{-1}$ and NPK @ 110:120:120 kg ha$^{-1}$ was applied uniformly to both cassava and groundnut (50-100-50 kg/ha – basal, 10-20-20 kg/ha – one month after planting (groundnut) and 50-0-50 kg/ha for the main crop after the harvest of groundnut) [3]. For cowpea, recommended dose of nutrients such as FYM @ 20 t ha$^{-1}$and NPK 20:30:10 kg ha$^{-1}$ was applied uniformly [3]. Along with the recommended nutrients, 0.5% foliar spray of 19-19-19 was applied on cassava + groundnut and cowpea at 30 and 14 days interval respectively. The varieties used for the study were 'Aiswarya' (rice), 'Vellayani Hraswa' (cassava), 'TMV-2' (groundnut) and 'Bhagyalakshmi' (cowpea). Observations on yield components, grain yield for rice, tuber yield for cassava, pod yield for groundnut and pod yield for cowpea were measured. System productivity in terms of rice equivalent yield of the system and energy budgeting was calculated using the standard formula:

$$\text{Rice equivalent yield} = \text{Rice grain yield} + \frac{\left(\text{Tuber yield} \times \text{Price of cassava}\right) + \left(\text{Pod yield} \times \text{Price of groundnut}\right) + \left(\text{Pod yield} \times \text{Price of cowpea}\right)}{\text{Price per kg of rice}}$$

The direct energy input and output were calculated in terms of Mega joules per hectare (MJ ha$^{-1}$) based on energy equivalent values for the various inputs and outputs:

Energy efficiency was worked out by dividing the energy output by the energy input as suggested by Devasenapathy *et al*. [4].

$$\text{Energy Efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

Specific energy was calculated in terms of energy required to produce one kilogram of main product and expressed in MJ kg$^{-1}$ as suggested by Dazhong and Pimental [5].

$$\text{Specific Energy} = \frac{\text{Total system input (MJ ha}^{-1})}{\text{Rice equivalent yield (kg ha}^{-1})}$$

Energy productivity describes the quantity of physical output obtained for every unit of input and expressed in kg MJ$^{-1}$ as suggested by Dazhong and Pimental [5].

$$\text{Energy Productivity} = \frac{\text{Rice equivalent yield (kg ha}^{-1})}{\text{Total system input (MJ ha}^{-1})}$$

Energy intensity (economic terms) is the ratio between energy output and cost of cultivation and expressed in MJ Rs$^{-1}$ as suggested by Devasenapathy *et al.* [4].

$$\text{Energy Intensity} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

The data were subjected to analysis of variance (ANOVA) as applied to Split Plot Design [6].

## RESULTS AND DISCUSSION

*Effect of treatments on yield of rice*

The significant effect of treatments can be observed on the yield of rice (Table 1). The highest grain yield of 2085.4 kg ha$^{-1}$ was recorded in dibbling of seeds using drum seeder + power weeding and was on par with dibbling of seeds using drum seeder + stubble mulching with a yield of 2068.1 kg ha$^{-1}$, compared to broadcasting of seeds during the first year [7]. The increase in yield was observed in dibbling of sprouted seeds with drum seeder along with power weeding and straw mulching could be due to proper spacing of plants which helps in better growth and establishment of tillers. Laary *et al*. [8] also reported that direct seed dibbling and direct seed drilling had better plant establishment and was significantly higher than pre-germinated seed broadcasting. Mechanical weeding would also contribute in enhancing the yield characters by suppressing the weeds for a long time compared to frequent hand weeding. When straw was used as mulch, it might have helped to conserve the nutrient reserves as well as the moisture in soil and also might have an additional effect on weed control which leads to more yield. During the second year the results indicated that the methods of planting and weed control measures did not have any significant effect on the grain yield of rice. During 2013-14, the effect of fertilizer application on the grain yield of rice was not significant. During 2014-15, the grain yield significantly influenced by the different methods of fertilizer application and also the yield was comparatively higher compared to the first year. The highest grain yield was recorded in the foliar spray of 19:19:19 @ 0.5% with an increase of 3.71 per cent compared to that of $F_2$ and $F_4$ respectively. The nutrients applied through foliage would be easily available and translocated in the plants without any loss [9].

Comparing the interaction effect, dibbling of seeds using drum seeder + power weeding along with band placement of 60:30:30 kg NPK ha$^{-1}$ ($m_2f_2$) produced the highest grain yield (2927.9 kg ha$^{-1}$) during the first year. The stubble mulch used as a weed control measure was not able to significantly influence the grain yield and the reason might be that straw mulch could effectively control weeds only during the early stage of crop growth. This finding justifies the implication of critical period of crop weed competition in aerobic rice as reported by [10]. During 2014-15 comparing the methods of planting and weed control practices along with fertilizer application methods, the highest grain yield of 3109.3 kg ha$^{-1}$ was obtained in dibbling of seeds using drum seeder + power weeding along with foliar spray of 19:19:19 @ 0.5%. The beneficial effect of cowpea grown as third crop in the sequence might have contributed sufficient nutrients through nitrogen fixation, which in turn helped to enhance the yield parameters and yield of rice along with foliar nutrition. Pointing out the superiority of cowpea and groundnut in increasing the yield of the first crop of rice in the system [11].

Table 1 Yield of rice, sequential crops (cassava + groundnut and cowpea) and rice equivalent yield influenced by the methods of planting, weed and nutrient management

| Treatments | Cassava Tuber yield (t/ha) | | Groundnut Pod yield (kg/ha) | | Cowpea Pod yield (kg/ha) | | Rice Grain yield (kg/ha) | | Rice equivalent yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | 2013-14 | 2014-15 | 2013-14 | 2014-15 | 2013-14 | 2014-15 | 2013-14 | 2014-15 | |
| Methods of planting and weed management (M) | | | | | | | | | |
| Broadcasting of seeds | 30.3 | 17.5 | 600.0 | 1056.8 | 454.2 | 523.56 | 1654.3 | 2436.2 | 24.0 |
| Dibbling of seeds+ power weeding | 29.1 | 16.4 | 552.2 | 1028.7 | 660.4 | 744.2 | 2085.4 | 2697.1 | 24.7 |
| Dibbling of seeds+ stubble mulching | 30.9 | 17.1 | 817.2 | 1182.4 | 540.8 | 1127.4 | 2068.1 | 2422.7 | 26.7 |
| SEm± | 0.103 | 0.292 | 17.119 | 4.348 | 95.952 | 15.287 | 46.282 | 104.819 | 0.525 |
| CD (0.05) | 0.237 | NS | 55.826 | 14.179 | NS | 49.852 | 150.931 | NS | 2.337 |
| Methods of fertilizer application (F) | | | | | | | | | |
| Broadcasting of 60-30-30 kg NPK/ha | 31.9 | 18.6 | 789.1 | 958.8 | 618.4 | 761.5 | 1922.2 | 2332.8 | 25.9 |
| Band placement of 60-30-30 kg NPK/ha | 31.7 | 16.9 | 626.0 | 1107.2 | 497.3 | 833.5 | 2053.2 | 2649.5 | 26.0 |
| Foliar spray of 19-19-19 @ 0.5% | 27.8 | 15.6 | 560.9 | 1005.3 | 577.4 | 775.9 | 1981.3 | 2747.7 | 23.8 |
| Foliar spray of DAP and SOP each @ 2% | 29.9 | 17.8 | 597.4 | 1370.7 | 532.3 | 793.1 | 1996.9 | 2634.7 | 25.8 |
| Absolute control | 29.2 | 16.1 | 708.89 | 1004.74 | 533.4 | 827.9 | 1726.1 | 2228.5 | 24.3 |
| SEm± | 0.873 | 0.245 | 28.970 | 7.703 | 16.654 | 18.849 | 79.956 | 86.373 | 0.677 |
| CD (0.05) | 1.756 | 0.696 | 82.391 | 21.907 | 47.364 | 53.606 | NS | 245.642 | 2.423 |
| Interaction (M×F) | | | | | | | | | |
| Broadcasting of seeds +broadcasting of 60-30-30 kg NPK/ha | 37.12 | 18.2 | 815.6 | 721.4 | 551.0 | 452.6 | 1679.1 | 1928.8 | 23.4 |
| Broadcasting of seeds + band placement of 60-30-30 kg NPK/ha | 31.4 | 18.9 | 451.6 | 1118.5 | 576.4 | 596.8 | 1598.6 | 2779.62 | 26.3 |
| Broadcasting of seeds + foliar spray of 19-19-19 @ 0.5% | 26.5 | 17.9 | 434.4 | 981.8 | 341.9 | 621.9 | 1727.9 | 2949.1 | 23.5 |
| Broadcasting of seeds + foliar spray of DAP and SOP each @ 2% | 28.4 | 15.4 | 332.8 | 1410.4 | 381.4 | 353.3 | 1693.8 | 2201.2 | 22.9 |
| Broadcasting of seeds + absolute control | 28.1 | 17.1 | 965.6 | 1028.6 | 420.1 | 593.8 | 1572.0 | 2151.7 | 24.1 |
| Dibbling of seeds + power weeding + broadcasting of 60-30-30 kg NPK/ha | 28.1 | 17.4 | 521.9 | 786.5 | 645.8 | 800.3 | 2207.1 | 2683.3 | 24.5 |
| Dibbling of seeds + power weeding + band placement of 60-30-30 kg NPK/ha | 30.0 | 18.6 | 764.1 | 1018.2 | 444.4 | 868.1 | 2927.9 | 3031.9 | 26.4 |
| Dibbling of seeds + power weeding + foliar spray of 19-19-19 @ 0.5% | 29.1 | 15.1 | 360.9 | 904.9 | 734.2 | 644.4 | 1603.8 | 3109.3 | 23.8 |
| Dibbling of seeds + power weeding + foliar spray of DAP and SOP each @ 2% | 30.3 | 16.4 | 779.7 | 1268.2 | 750.9 | 721.9 | 2221.9 | 2950.4 | 25.9 |
| Dibbling of seeds+ power weeding + absolute control | 27.8 | 14.5 | 334.4 | 1165.4 | 726.5 | 686.3 | 1753.8 | 1878.2 | 22.7 |
| Dibbling of seeds + stubble mulching + broadcasting of 60-30-30 kg NPK/ha | 30.34 | 20.3 | 1029.7 | 1368.5 | 658.3 | 1126.3 | 1880.5 | 2383.3 | 29.7 |
| Dibbling of seeds + stubble mulching + band placement of 60-30-30 kg NPK/ha | 33.7 | 15.7 | 662.5 | 1184.9 | 471.3 | 1036.3 | 1705.0 | 2218.5 | 25.4 |
| Dibbling of seeds + stubble mulching + foliar spray of 19-19-19 @ 0.5% | 27.7 | 13.9 | 887.5 | 1129.1 | 663.8 | 1061.3 | 2533.0 | 2184.8 | 24.0 |
| Dibbling of seeds+ stubble mulching+ foliar spray of DAP and SOP each @ 2% | 30.9 | 19.1 | 679.6 | 1433.6 | 481.3 | 1209.3 | 2075.0 | 2671.1 | 28.1 |
| Dibbling of seeds+ stubble mulching + absolute control | 31.6 | 16.7 | 826.6 | 819.0 | 429.3 | 1203.6 | 1852.4 | 2655.7 | 26.0 |
| SEm± | 1.513 | 0.424 | 50.178 | 13.343 | 28.845 | 32.647 | 138.488 | 149.603 | 1.173 |
| CD (0.05) | 3.042 | 1.205 | 142.705 | 37.945 | 82.036 | 92.848 | 393.854 | 425.464 | 3.484 |

For rice equivalent yield, the prices of different crops were: rice Rs 18/kg, cassava Rs 15/kg, groundnut Rs 40/kg, cowpea Rs 40/kg

*Residual effect of treatments of rice on yield of sequential crops (cassava intercropped groundnut and cowpea)*

The residual effect of treatments applied to rice was not observed on cassava tuber yield in the second year but in the initial year, the residual effect of dibbling of seeds + stubble mulching significantly produced 30.86 t/ha tuber and the increase in yield was 1.81 and 6.05 per cent compared to residual effect of broadcasting of rice seeds and dibbling of seeds + power weeding. The stubble mulching and intercrop might help in increasing the soil moisture content as well as reduced the weeds and could have fixed some amount of nitrogen by groundnut at the time of incorporation as found by [12]. The residual effect of soil application of 60-30-30 kg NPK/ha as broadcasting produced higher tuber yields during both the years (31.9 and 18.7 t/ha respectively) and was statistically at par with residual effect of band placement of 60-30-30 kg NPK/ha (2013-14) and foliar spray of DAP and SOP each @ 2% (2014-15). The improvement in the number of functional leaves / plant might have resulted in better productivity. Moreover, the high residual soil nutrients of the previous rice along with the nutrients (soil and foliar) applied to cassava as well as the nutrients supplied from the incorporated groundnut have contributed to higher cassava yield. The residual effect of combination of dibbling of seeds + stubble mulching along with broadcast application of 60-30-30 kg NPK/ha to the first crop rice produced the highest cassava tuber yield of 36.7 t/ha (2013-14) and 20.3 t/ha (2014-15). These interactions were significantly superior to all the other combinations, except residual effect of broadcasting of seeds + broadcast application of 60-30-30 kg NPK/ha in the first year and dibbling of seeds + stubble mulching along with foliar spray of DAP and SOP each @ 2% in the second year, which were statistically similar. The residual nutrients and moisture conserved by stubble mulching also might added to the higher cassava tuber yield.

Data presented in (Table 1) revealed that the residual effect of stubble mulching using rice straw resulted in the highest pod yield of groundnut during both the years, which was significantly different from the carry over effect of the other two methods of weed control. The residual effect of available soil nutrient content after the rice crop might have enhanced the yield attributes of succeeding groundnut. Comparing the fertilizer application methods, the residual effect of broadcast application of 60-30-30 kg NPK/ha resulted in the highest pod yield of 789.1 kg/ha in the first year which was on par with absolute control. During 2014-15, the highest groundnut pod yield was resulted in the residual effect of DAP and SOP each @ 2% foliar spray with an increase of 23.08% compared to band placement of 60-30-30 kg NPK/ha. Similar findings were reported by Singh and Lakpale [13] in soybean which produced maximum number of pods per plant, number of seeds per pod, seed index and higher grain yield by the application of recommended dose of fertilizer and spray of DAP @ 2% at pod initiation stage. The residual effect of treatment combination, dibbling of seeds + stubble mulching along with broadcast application of 60-30-30 kg NPK/ha was found to record the highest pod yield which was significantly different from the other treatment combinations during the first year. In the second year, pod yield was higher in residual effect of dibbling of seeds + stubble mulching and broadcasting of seeds both along with DAP and SOP each @ 2% foliar spray (1433.6 kg/ha and 1410.4 kg/ha respectively) which was significantly superior to other interactions. The similar results were observed by Singh and Singh [14], where foliar application of DAP twice met out N and P requirement at the critical stages of the chick pea crop due to ensured and prompt delivery of mineral nutrients to the site of photosynthesis, which leads to higher yield.

The residual effect of stubble mulching applied to the preceding first crop rice was found to produce the highest pod yield of cowpea during two years. Among the fertilizer application methods, during first year maximum pod yield of 618.4 kg per ha was produced by the residual effect of broadcasting of 60-30-30 kg NPK/ha in rice which was statistically at par with foliar spray of 19-19-19 @ 0.5 %. Similar results were obtained in the second year also. Surgyan *et al.* [15] reported that application of N, P, K through foliar supplementation significantly influenced the grain weight per ear head, grain yield and biological yield of pearl millet. Comparing the treatment combinations, dibbling of seeds + power weeding along with foliar spray of DAP and SOP each @ 2 % resulted in the highest pod yield during the first year, which was on par with the other treatments except dibbling of seeds+ power weeding along with foliar spray of 19-19-19 @ 0.5% as well as control. During the second year, the highest pod yield was obtained from the residual effect of dibbling of seeds + stubble mulching along with foliar spray of DAP and SOP each @ 2% in rice, which was significantly superior to all other treatments, except dibbling of seeds+ stubble mulching along with broadcasting of 60-30-30 kg NPK/ha in rice as well as control, which were on par. The direct effect of applied nutrients and nitrogen fixation by cowpea and groundnut as well as the nutrient released by the decomposition of straw in rice might have contributed to higher yield in the best treatment [16].

*System productivity (Rice equivalent yield)*

The residual effect of dibbling of seeds + stubble mulching recorded the highest rice equivalent yield while taking the average of two years study and produced 9.54% and 7.33% more rice equivalent yield than broadcasting of seeds and dibbling of seeds + power weeding respectively. Residue incorporation in conventional tillage practiced in rice - wheat cropping system for long term period resulted in significantly higher system productivity than other treatments reported by Ranbir *et al.* [17] also supports the present investigation. The residual effect of soil (broadcasting and band placement of 60-30-30kg NPK/ha) as well as foliar application of fertilizer (foliar spray of DAP and SOP each @ 2%) resulted in higher rice equivalent yield. Regarding the treatment combinations, the treatment combination of dibbling of seeds + stubble mulching along with broadcasting of 60-30-30 kg NPK/ha produced the highest rice equivalent yield of 29.7 t/ha, which was superior to all the other combinations, except dibbling of seeds + stubble mulching along with foliar spray of water-soluble complex fertilizer DAP and SOP each @ 2% with an increase of 5.77%. Favorable individual effect of these treatments on yield of component crops in the system enhanced the rice equivalent. The foliar fertilizers alone were not able to increase the system yield because it might not have made available the residual nutrients for a prolonged period as effective as that of soil applied fertilizers [18].

*Energy budgeting of cropping system*

*Energy efficiency*

The results presented in (Table 2) indicated that the direct and residual effect of treatments and their interaction had significant effect on the energy efficiency of cropping system in both the years. Among the methods of planting and weed management practices, the highest energy efficiency was registered in dibbling of seeds which was on par with dibbling of seeds + power weeding during both the years. The energy efficiency of the various fertilizer application methods was assessed and it was found that, the highest energy efficiency was registered in $F_3$ which was on par with $F_5$ in the first year. In the second year, the highest energy efficiency of 28.86 was observed in $F_4$, which produced the highest yield and was on par with $F_3$ and $F_5$. Comparing the interactions, the direct and residual effect of $m_2f_4$ resulted in the highest energy efficiency during both the years without considering the control since the treatment produced the higher yield compared to control.

*Energy productivity*

Direct and residual effect of broadcasting of seeds ($M_1$) as well as dibbling of seeds with power weeding ($M_2$) produced significantly highest value of energy productivity as compared to $M_3$ in the first year (Table 2). During the second year, $M_2$ resulted in the highest energy productivity of 0.39 kg $MJ^{-1}$ and it was on par with $M_1$. The highest energy productivity was recorded in $F_4$ with a value of 0.45 kg $MJ^{-1}$ among the various fertilizer application methods, which was on par with $F_5$ during 2013-14. In the second year, the direct and residual effect of $F_4$ resulted in significantly the highest energy productivity which was on par with other fertilizer application methods, except $F_1$

and $F_2$. Among the treatment combinations, the direct and residual effect of $m_1f_1$ and $m_2f_4$ produced the higher energy productivity (0.54 kg $MJ^{-1}$) in the first year which was significantly different from all the other combinations, except $m_1f_5$. In the second year, the highest energy productivity was registered in $m_1f_3$ and was on par with $m_1f_5$ and $m_2f_4$.

Table 2 Direct and residual effect of treatments on energy budgeting of rice –cassava + groundnut - cowpea system

| Treatments | Energy efficiency | | Energy productivity (Kg $MJ^{-1}$) | | Specific energy (MJ $kg^{-1}$) | | Energy intensity (MJ $Rs^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | 2013-14 | 2014-15 | 2013-14 | 2014-15 | 2013-14 | 2014-15 | 2013-14 | 2014-15 |
| Main plot (M) | | | | | | | | |
| $M_1$ | 22.31 | 28.22 | 0.49 | 0.38 | 2.10 | 2.68 | 3.85 | 4.71 |
| $M_2$ | 22.26 | 29.17 | 0.49 | 0.39 | 2.12 | 2.61 | 4.19 | 5.08 |
| $M_3$ | 18.61 | 22.17 | 0.31 | 0.24 | 3.32 | 4.24 | 4.10 | 4.37 |
| SEm± | 0.276 | 0.507 | 0.007 | 0.003 | 0.079 | 0.037 | 0.045 | 0.105 |
| CD (0.05) | 0.899 | 1.652 | 0.022 | 0.010 | 0.260 | 0.122 | 0.147 | 0.341 |
| Sub plot (F) | | | | | | | | |
| $F_1$ | 20.25 | 23.24 | 0.42 | 0.30 | 2.58 | 3.45 | 4.04 | 4.26 |
| $F_2$ | 18.21 | 24.15 | 0.41 | 0.32 | 2.59 | 3.35 | 4.00 | 4.91 |
| $F_3$ | 22.94 | 28.17 | 0.43 | 0.35 | 2.53 | 3.18 | 3.98 | 4.63 |
| $F_4$ | 20.51 | 28.86 | 0.45 | 0.36 | 2.41 | 2.88 | 3.83 | 4.89 |
| $F_5$ | 23.83 | 28.17 | 0.45 | 0.35 | 2.48 | 3.02 | 4.38 | 4.91 |
| SEm ± | 0.407 | 0.399 | 0.007 | 0.004 | 0.080 | 0.035 | 0.093 | 0.114 |
| CD (0.05) | 1.159 | 1.133 | 0.019 | 0.012 | NS | 0.099 | 0.263 | 0.323 |
| Interaction (M×F) | | | | | | | | |
| $M_1F_1$ | 23.09 | 19.87 | 0.54 | 0.28 | 1.90 | 3.54 | 3.98 | 3.78 |
| $M_1F_2$ | 17.93 | 26.28 | 0.46 | 0.38 | 2.27 | 2.62 | 3.58 | 4.93 |
| $M_1F_3$ | 23.23 | 31.49 | 0.46 | 0.44 | 2.25 | 2.28 | 4.13 | 4.92 |
| $M_1F_4$ | 19.32 | 28.71 | 0.47 | 0.38 | 2.12 | 2.63 | 3.08 | 4.33 |
| $M_1F_5$ | 27.10 | 34.73 | 0.52 | 0.43 | 1.98 | 2.35 | 4.50 | 5.58 |
| $M_2F_1$ | 17.72 | 25.55 | 0.43 | 0.35 | 2.41 | 2.88 | 4.10 | 4.60 |
| $M_2F_2$ | 20.47 | 25.13 | 0.46 | 0.38 | 2.23 | 2.62 | 4.70 | 5.20 |
| $M_2F_3$ | 22.49 | 30.42 | 0.51 | 0.39 | 2.01 | 2.56 | 3.58 | 5.28 |
| $M_2F_4$ | 25.45 | 33.66 | 0.54 | 0.42 | 1.91 | 2.36 | 4.50 | 5.61 |
| $M_2F_5$ | 25.16 | 31.10 | 0.51 | 0.38 | 2.06 | 2.62 | 4.06 | 4.71 |
| $M_3F_1$ | 19.95 | 24.31 | 0.30 | 0.25 | 3.42 | 3.94 | 4.04 | 4.39 |
| $M_3F_2$ | 16.23 | 21.04 | 0.31 | 0.21 | 3.26 | 4.82 | 3.73 | 4.57 |
| $M_3F_3$ | 23.09 | 22.61 | 0.31 | 0.21 | 3.33 | 4.69 | 4.21 | 3.70 |
| $M_3F_4$ | 16.76 | 24.21 | 0.32 | 0.27 | 3.20 | 3.67 | 3.91 | 4.73 |
| $M_3F_5$ | 17.02 | 18.67 | 0.33 | 0.25 | 3.41 | 4.08 | 4.60 | 4.45 |
| SEm± | 0.706 | 0.690 | 0.012 | 0.008 | 0.139 | 0.060 | 0.161 | 0.197 |
| CD (0.05) | 2.007 | 1.963 | 0.034 | 0.021 | NS | 0.171 | 0.456 | 0.559 |

*Specific energy*

During both the years, direct as well as residual effect of dibbling of seeds with stubble mulching resulted in significantly the higher values of specific energy which was significantly superior to other two methods of planting and weed control measures. The direct as well as residual effect of various fertilizer application methods did not show any significant variation in the first year. During 2014-15, the highest specific energy was registered in $F_1$ which was on par with $F_2$. The specific energy was not influenced by the different treatment combinations during 2013-14. In the second year, the direct and residual effect of $m_3f_2$ produced significantly the highest value which was superior to all the other interactions, except $m_3f_3$ which was on par.

*Energy intensity*

Comparing the methods of planting and weed control practices, direct as well as residual effect of $M_2$ resulted in significantly the highest energy intensity value in the first and second years (4.19 and 5.08 MJ $Rs^{-1}$ respectively). The treatment was on par with $M_3$ in the first year (2013-14). Comparing the methods of fertilizer application, during the first year, the highest energy intensity was registered in $F_1$ without considering the control ($F_5$), since $F_1$ produced the highest system yield than control. In the second year, the direct and residual effect of $F_2$ resulted in the higher value and was on par with all the other treatments except $F_1$. The direct as well as residual effect of $m_2f_2$ resulted in the highest energy intensity (4.70 MJ $Rs^{-1}$) and was significantly superior to all the other interactions except $m_1f_5$, $m_2f_4$ and $m_3f_5$ which were on par with $m_2f_2$ in the first year. During 2014-15, the highest energy intensity was recorded in the treatment combination of $m_2f_4$, which was on par with $m_1f_5$, $m_2f_2$ and $m_2f_3$.

The highest energy efficiency, energy productivity and energy intensity were observed in the direct and residual effect of dibbling of seeds using drum seeder + power weeding during both the years of experimentation. The mechanical weeding might have helped to reduce the labour and weed population and thereby the energy utilized for each unit of labour was reduced. Each unit of energy might have been effectively utilized for the production of yield attributes and yield of the cropping system. Specific energy gives an indication of energy required per unit quantity of economic produce. It is always essential to have lower specific energy for higher efficiency. In the system under study, dibbling of seeds using drum seeder + power weeding resulted in the lowest value which might be due to the less energy utilized for labour in sowing and weeding.

## SUMMARY

It can be concluded that the direct and residual effect of dibbling of rice seeds using drum seeder + stubble mulching @ 3 t/ha as well as power weeding along with either soil application of 60-30-30 kg NPK/ha as broadcasting to rice or foliar spray of DAP and SOP each @ 2% to rice was found to be the energy efficient and sustainable rice-based cropping system in upland.

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